A SUBMARINE VESSEL IN BATTLE.

The "Argonaut" may approach her enemy with only her observing tower above the surface, and as this is armored and presents such a small target it could not be hit with a ball of sufficient caliber to do any harm; or she may approach on the bottom and rise up under the enemy if at anchor, and secure a time-fuse torpedo to her bottom; or she may be fitted with tubes to fire automobile torpedoes. In the latter case she need not approach nearer than 300 or 400 yards.

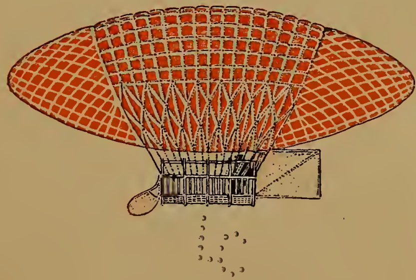
THE BOY'S BOOK OF INVENTIONS.

THE BOY'S BOOK OF INVENTIONS

STORIES OF THE WONDERS OF MODERN SCIENCE

BY

RAY STANNARD BAKER



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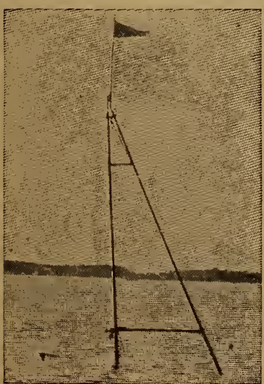
A VOYAGE ON THE BOTTOM OF THE SEA.

Simon Lake's Submarine Boat, the "Argonaut."



AT THE BOTTOM OF THE ATLANTIC.

The "Argonaut" here lies submerged in twenty-eight feet of water.

SIMON LAKE'S curious craft, the "Argonaut," is a submarine boat, and much more besides. She not only swims beneath the surface of the water and upon it, but she adds to these accomplishments the extraordinary power of diving deep, and rolling along the bottom of the sea on wheels. No machine ever before did that. Indeed, the "Argonaut" is more properly a "sea-motocycle" or "sea-tricycle" than

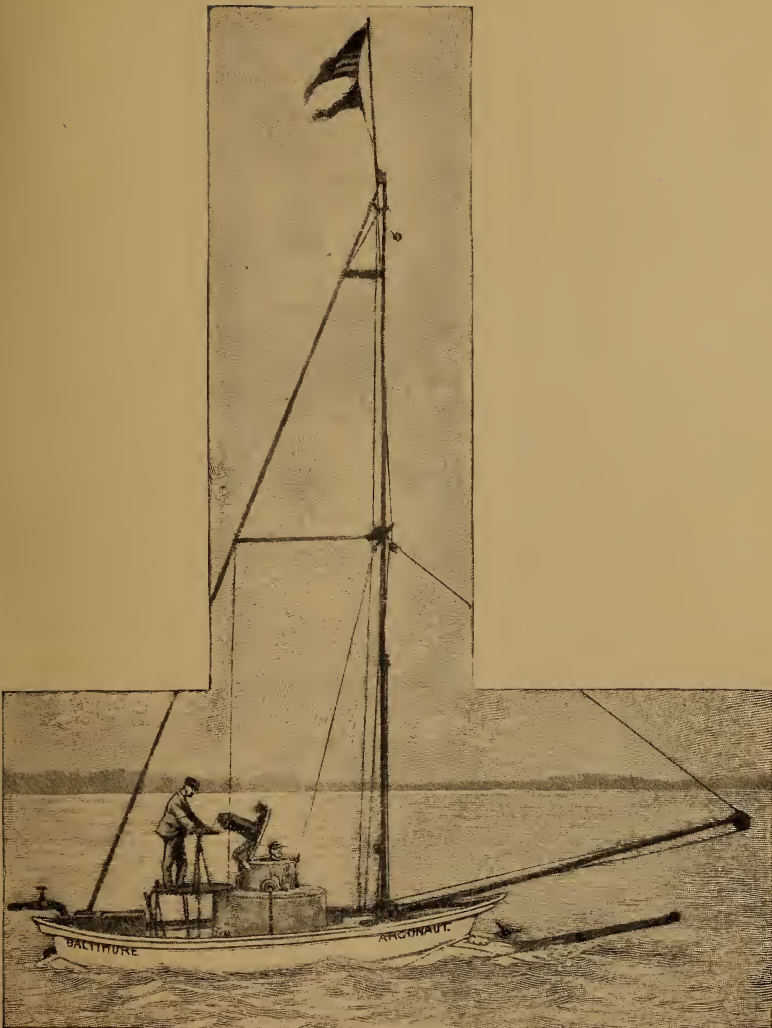
a boat. The inventor himself has described it as "a boat-wagon for riding on the bottom of the sea."

In October, 1898, the "Argonaut" lay off the pier at Atlantic Highlands, New Jersey. She had just finished a tedious voyage from Baltimore, where she was built, and she was quietly anchored from a barrel buoy. Mr. Lake had invited Mr. Stevens, the artist, and myself to make a trip with him on the bottom of the ocean. As we walked up the pier, we watched eagerly for the first glimpse of the wonderful sea-wagon of which we had heard so many strange stories.

"There she lies," said Mr. Lake, not without a touch of pride in his voice.

But all we could see was a great black letter A, made of gas-pipe, rising forty feet above the water. A flag rippled at its summit. As we drew nearer, we saw that the big A rested on a small oblong deck, shouldering deep in the water. At the center of this deck there was a slightly higher platform surmounted by an iron tower about the size of a small barrel. A curious brass cap which covered the top of the tower was tilted back, and as our boat ran alongside, a man stuck his head up over the rim and sang out,

"Ahoy there!"



THE "ARGONAUT" SAILING ON THE SURFACE.

From a photograph.

A considerable sea was running, but I observed that the "Argonaut" was planted as firmly in the water as a stone pillar, the big waves splitting over her without imparting any perceptible motion.

"She weighs fifty-seven tons," said Mr. Lake, "and there are only two or three tons above water. I never have seen the time when she rolled."

We scrambled up on the little platform and peered down through the open tower—"conning-tower," Mr. Lake called it—into the depths of the ship below. Wilson, the engineer, had started the fire in his gasolene engine, and it wasn't long before we saw a white plume of steam rising from the very summit of the gas-pipe frame above us.

"This leg of the A," explained Mr. Lake, "carries off the burnt gases, and this one brings in the fresh air while we are submerged. You see the pipes are tall enough, so that we can use them until we are more than fifty feet under water. Below that we have to depend on the compressed air in our tanks, or on a hose reaching from the upper end of the pipe to a buoy on the surface."

Mr. Lake had taken his place at the wheel, and we were going ahead slowly, steering straight across the bay toward Sandy Hook

and deeper water. The "Argonaut" makes about five knots an hour on the surface, but when she gets deep down on the sea bottom, where she belongs, she can spin along more rapidly.

"Are you ready to go down?" asked Mr. Lake.

The waves were already washing entirely over the lower platform and occasionally breaking around our feet, but we both nodded solemnly.

"Open the center compartments," Mr. Lake shouted down the conning tower. "I'm flooding the air ballast compartments," he explained. "Usually we submerge by letting down two half-ton iron weights and then, after admitting enough water to overcome our buoyancy, we can readily pull the boat to the bottom by winding in on the weight cables. Unfortunately we have lost one of the weights, and so we have to depend entirely on the compartments."

The "Argonaut" was slowly sinking under the water. We became momentarily more impressed with the extreme smallness of the craft to which we were trusting our lives. The little platform around the conning tower on which we stood—in reality the top of the gasolene tank—was scarcely a half-dozen feet across,

and the "Argonaut" herself was only thirty-six feet long. Her sides had already faded out of sight, but not before we had seen how solidly they were built, all of steel, riveted and re-enforced, so that the wonder grew how such a tremendous weight, when submerged, could ever again be raised.

"We had to give her immense strength," said Mr. Lake, "to resist the water pressure at great depths. She is built of the same thickness of steel as the government used for the 2,000-ton cruisers 'Detroit' and 'Montgomery.' She'll stand a hundred feet, although we never took her deeper than fifty. We like to keep our margins safe."

I think we made some inquiries about the safety of submarine boats in general. Other air compartments had been opened, and we had settled so far down that the waves dashed repeatedly over the platform on which we stood—and the conning-tower was still wide open, inviting a sudden engulfing rush of water.

"You mustn't confuse the 'Argonaut' with ordinary submarine boats," said Mr. Lake. "She is quite different and much safer. When I first began experimenting, I saw that the greatest problem of submarine navigation was the inability to steer accurately when sub-

SUBMERGING THE "ARGONAUT."

The man is looking up through the conning-tower at the compass.

merged. You see, below the surface of the water you have four directions in which you may go instead of two, as on the surface, and no one has yet succeeded in inventing a rudder that will keep a submarine boat in a steady course, so that it will not leap out of water at

one moment and plunge to the bottom at the next. I simply gave up the problem and decided to run on the bottom, where I can steer as easily as if I were on shore."

That was originality; it was so simple that no one ever had dreamed of trying it before.

"I think we'd better go below," said Mr. Lake, with a trace of haste in his voice.

I went first, slipping hand over hand down the ladder. Mr. Stevens followed, and a great wave came slapping in after him, sousing down over his shoulders. Mr. Lake quickly shut down the conning-tower cap and screwed it fast over its rubber rims.

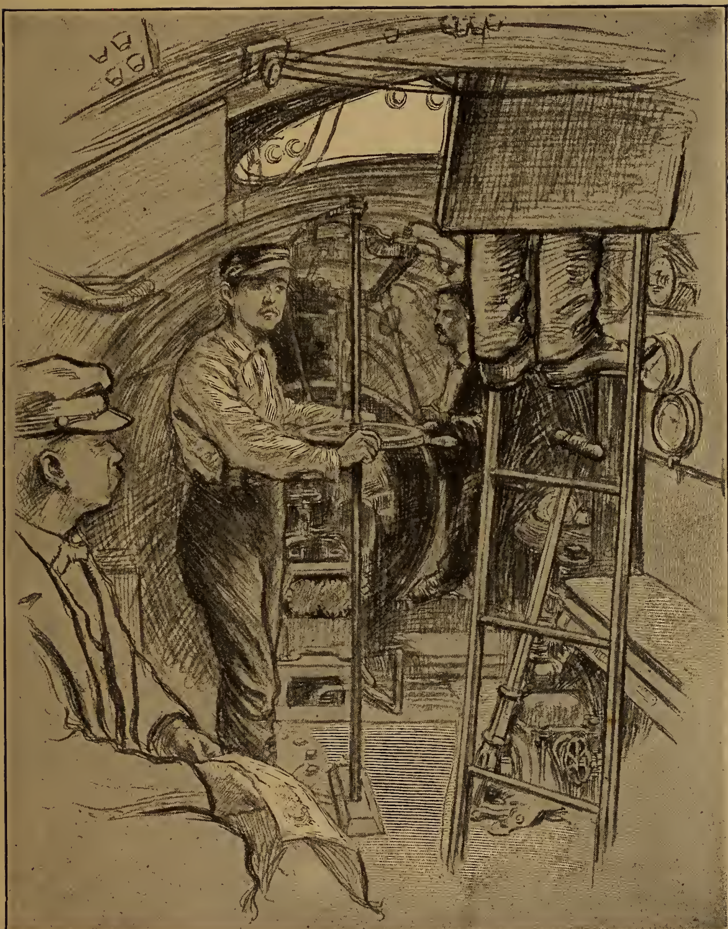
We found ourselves in a long, narrow compartment, dimly illuminated by yellowish-green light from the little, round glass windows. The stern was filled with Wilson's gasolene engine and the electric motor, and in front of us, toward the bow, we could see through the heavy steel doorways of the divers' compartment into the lookout-room, where there was a single round eye of light.

"She's almost under," said Mr. Lake.

I climbed up the ladder of the conning-tower and looked out through one of the glass ports. My eyes were just even with the surface of the water. In the trough of the waves I could catch a glimpse of the distant sunny shores of

New Jersey, and here and there, off toward Staten Island, the bright sails of oyster smacks. Then the next wave came driving and foaming entirely over the top of the little vessel, and I could see the curiously beautiful sheen of the bright summit of the water above us. It was a most impressive sight. Not many people ever have had the opportunity of looking calmly upon the surface of the sea from below. Mr. Lake told me that in very clear water it was difficult to tell just where the air left off and the water began; but in the muddy bay, where we were going down, the surface looked like a peculiarly clear, greenish pane of glass moving straight up and down, not forward, as the waves appear to move when seen from above.

Now we were entirely under water. The ripping noises that the waves had made in beating against the upper structure of the boat had ceased. As I looked through the thick glass port, the water was only three inches from my eyes, and I could see thousands of dainty, semi-translucent jelly-fish floating about us lightly as thistle down. They gathered in the eddy behind the conning-tower in great numbers, bumping up sociably against one another, and darting up and down with each gentle movement of the water. And I



THE "ARGONAUT" SUBMERGED—A SCENE IN THE LIVING-ROOM.

On the left, Mr. Lake is seated; the steersman is in the center. The feet of the lookout in the conning-tower can be seen on the ladder to the right.

realized that we were in the domain of the fishes.

I returned to the bottom of the boat, to find that it was brilliantly lighted by electricity, and to have my ears pain me sharply.

"You see, the air is beginning to come down," said Jim, the first mate, "and we are getting a little pressure."

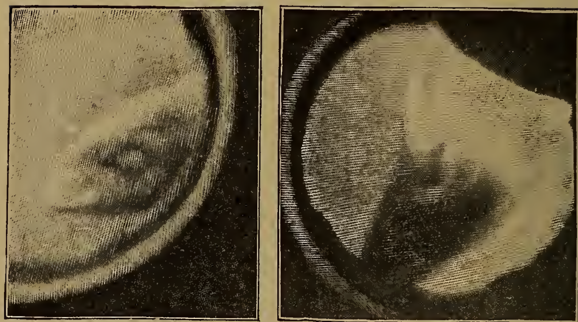
I held up my hand and felt the strong gust which was being drawn down through the tall air-pipe above us. It was comforting to know that the air arrangements were in working order.

Mr. Lake now hung a small mirror at an angle of forty-five degrees, just at the bottom of the conning-tower, and stepped back to the steering wheel. Upon looking into the mirror he could see the reflection of the compass, which is placed at the very highest tip of the brass binnacle that crowns the conning-tower.

"We can't use a compass down here," said Mr. Lake, "because there is too much machinery and steel."

Mr. Lake has found by repeated experiments that the compass points as accurately under water as on the surface.

Jim, the mate, brought the government chart, and Mr. Lake announced that we were heading directly for Sandy Hook and the open



FISH LOOKING IN AT THE WINDOW OF THE "ARGONAUT."

Both pictures are from photographs taken by Mr. Lake out of the forward lookout window of the "Argonaut," while she was running up the Patapsco River to Baltimore.

ocean. But we had not yet reached the bottom, and John was busily opening air compartments and letting in more water. I went forward to the little steel cubby-hole in the extreme prow of the boat, and looked out through the watch-port. The water had grown denser and yellower, and I couldn't see much beyond the dim outlines of the ship's spar reaching out forward. Jim said that he had often seen fishes come swimming up wonderingly to gaze into the port. They would remain quite motionless until he stirred his head, and then they vanished instantly. Mr. Lake has a remarkable photograph which he took of a visiting fish, and Wilson tells of nurturing a queer flat crab for days in the crevice

of one of the view-holes. As I turned from the watch-port, my eye fell on an everyday-looking telephone, with the receiver comfortably hung up next the steel walls.

"Oh, yes," said Jim, "we have all the modern conveniences. That's for telephoning to the main part of the boat when the diver's compartment is closed and we can't get through."

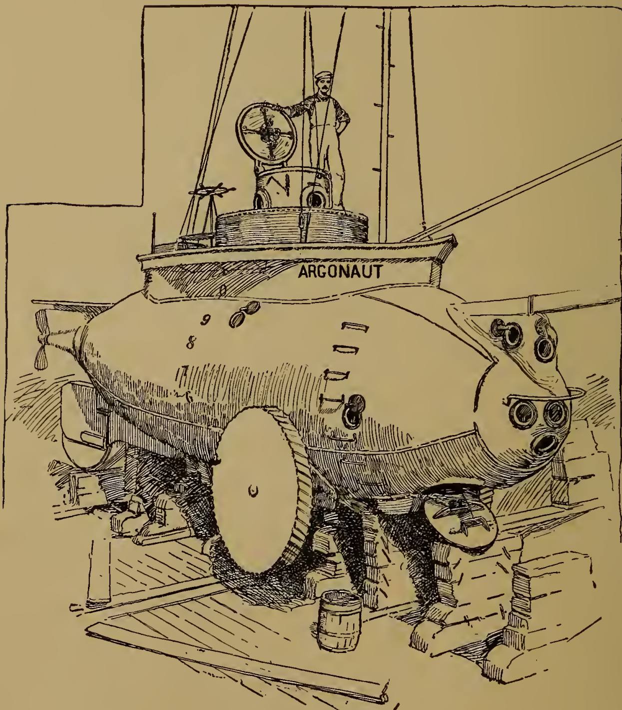
He also showed me a complex system of call-bells by means of which the man at the lookout could direct the engineer.

"When we are down in unknown waters," he said, "we have a big electric search-light which points out the way."

At that moment I felt a faint jolt, and Mr. Lake said that we were on the bottom of the sea, thirty feet below the surface.

"The bottom here is very muddy," he said, "and we are only resting a few hundred pounds' weight on our wheels. By taking in or pumping out water we can press down on the bottom like a locomotive or like a feather. Where we have good hard sand to run on we use our wheels for propelling the boat; but in mud like this, where there's nothing to get hold of, we make our propeller do the work."

Here we were running as comfortably along the bottom of Sandy Hook Bay as we would ride in a Broadway car, and with quite as much



THE "ARGONAUT" IN DRY-DOCK.

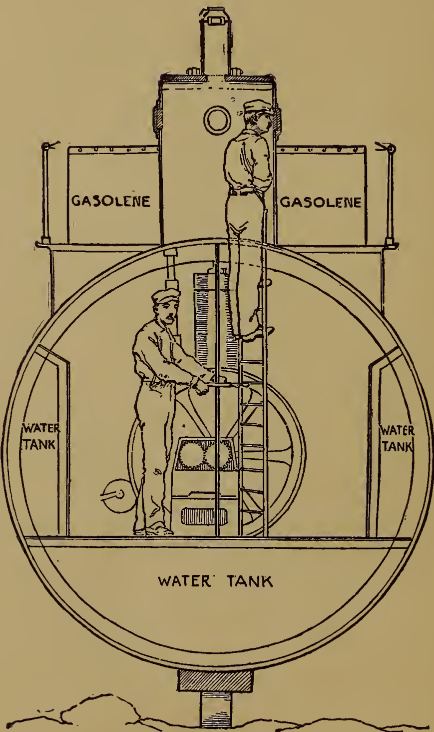
Drawn from photographs by Mr. Lake. The door of the diver's compartment, just under the bow, is open, and resting on some of the keel-blocks. Through this door the divers leave the boat when it is submerged, compressed air in the compartment preventing the entrance of water.

safety. Wilson, who was of a musical turn, was whistling "Down went McGinty," and Mr. Lake, with his hands on the pilot wheel, put in an occasional word about his marvelous invention. On the wall opposite there was a

row of dials which told automatically every fact about our condition that the most nervous of men could wish to know. One of them shows the pressure of air in the main compartment of the boat, another registers vacuum, and when both are at zero, Mr. Lake knows that the pressure of the air is normal, the same as it is on the surface, and he tries to maintain it in this condition. There are also a cyclometer, not unlike those used on bicycles, to show how far the boat travels on its wheels; a depth gauge which keeps us accurately informed as to the depth of the boat in the water; and a declension indicator. By the long finger of the declension dial we could tell whether we were going up hill or down. Once, while we were out, there was a sudden sharp shock, the pointer leaped back, and then quivered steady again. Mr. Lake said that we had probably struck a bit of wreckage or an embankment, but the "Argonaut" was running so lightly that she had leaped up jauntily and slid over the obstruction.

Strange things has Mr. Lake discovered about the bottom of the sea. He has found that nearly all sea roads are level, a fact of great importance to sea carriages like the "Argonaut."

"People get the impression from the sea-



AMIDSHIPS CROSS SECTION OF THE "ARGONAUT."

bottom contours of the school-books," he says, "that the ocean is filled with vast mountain ranges and deep valleys. As a matter of fact, these contours, in representing thousands of miles of width on a printed page, greatly exaggerate the depth, which at its greatest is only a few thousand feet, thus giving a very

false idea. Some shores slope more than others, but I venture to say that there are few spots on the bottom of the Atlantic that would not be called level if they were bare of water."

We had been keeping our eyes on the depth dial, the most fascinating and interesting of any of the number. It showed that we were going down, down, down. When we had been submerged for more than an hour, and there was thirty feet of yellowish-green ocean over our heads, Mr. Lake suddenly ordered the machinery stopped. The clacking noises of the dynamo ceased, and the electric lights blinked out, leaving us at once in almost absolute darkness and silence. Before this we had found it hard to realize that we were on the bottom of the ocean; now it came upon us suddenly, and not without a touch of awe. This absence of sound and light, this unchanging motionlessness and coolness, this absolute negation—this was the bottom of the sea. It lasted only a moment, but in that moment we realized acutely the meaning and joy of sunshine and moving winds, trees, and the world of men.

A minute light twinkled out like a star, and then another and another, until the boat was bright again, and we knew that among the other wonders of this most astonishing of inventions there was storage electricity which

would keep the boat illuminated for hours without so much as a single turn of the dynamo. With the stoppage of the engine the air supply from above had ceased, but Mr. Lake laid his hand on the steel wall above us, where, he said, there was enough air compressed to last us all for two days should anything happen.

Indeed, the possibility of "something happening" had been lurking in our minds ever since we started.

"What if your engine should break down so that you couldn't pump the water out of the air compartments?" I asked.

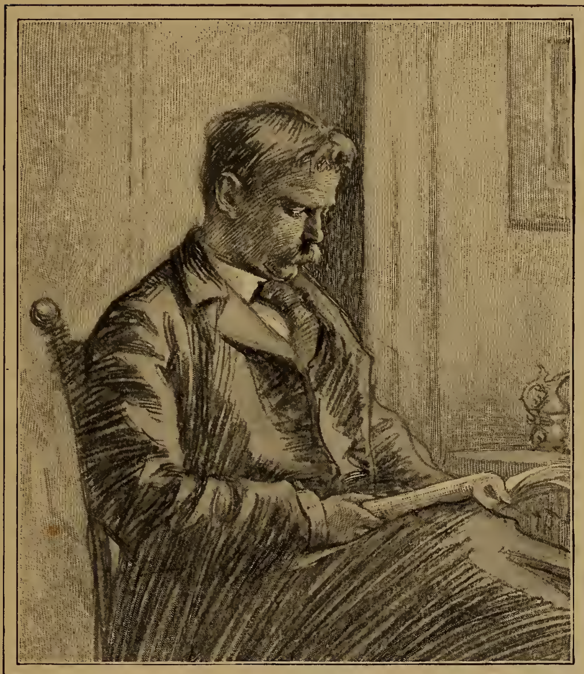
"Here we have hand pumps," said Mr. Lake promptly, "and if those failed, a single touch of this lever would release our lead keel, which weighs three thousand pounds, and up we would go like a rocket."

I questioned further, only to find that every imaginable contingency, and some that were not at all imaginable to the uninitiated, had been absolutely provided for by the genius of the inventor. And everything from the gasolene engine to the hand pump was as compact and ingenious as the mechanism of a watch. Moreover, the boat was not crowded; we had plenty of room to move around and to sleep, if we wished, to say nothing of eating.

Indeed, John had brought out the kerosene

RESTING UNDER THE SEA.

From a flash-light photograph of the "Argonaut's" crew "turned in" in the living-room. The door in front opens into the air-lock, diver's room, and forward lookout compartment (see the longitudinal section). On the right is the telephone by which communication is maintained with the forward compartments when the diver's room is in use.



SIMON LAKE.

Drawn from life by W. D. Stevens at Atlantic Highlands, October 16, 1898.

stove, and was making coffee while Jim cut the pumpkin pie.

"This isn't Delmonico's," said Jim, "but we're serving a lunch that Delmonico's couldn't serve—a submarine lunch."

By this time the novelty was wearing off, and we sat there at the bottom of the sea,

drinking our coffee with as much unconcern as though we were in an uptown restaurant. For the first time since we started, Mr. Lake sat down, and we had an opportunity of talking with him at leisure. He is a stout-shouldered, powerfully built man in the prime of life, a man of cool common sense, a practical man, who is also an inventor. And he talks frankly and convincingly and yet modestly of his accomplishment.

"When I was ten years old," he said, "I read Jules Verne's 'Twenty Thousand Leagues under the Sea,' and I have been working on submarine boats ever since."

At seventeen he invented a mechanical movement; at twenty he was selling a steering gear which he had just patented. In 1894 he began to build his first submarine boat. Like the practical man he was, he decided to make a practical boat. Most submarine-boat building, he thinks, is like Arctic exploration. It would be a nice thing to find the North Pole, but it wouldn't be of much use after it was found.

"I don't depend on the government to buy my boat," he said, "although I am sure it will be indispensable in warfare for placing torpedoes, cutting cables, and so on. The main object of boats of the 'Argonaut' type is commercial, to assist in raising sunken vessels,

THE SUBMARINE BOAT "ARGONAUT" ON A WRECKING EXPEDITION.

removing the treasure from wrecks, placing difficult submarine foundations, and any kind of work that requires diving. There are millions of gold in old wrecks right around New York, and I confidently believe that we can get some of it."

Having finished our lunch, Mr. Lake prepared to show us something about the practical operations of the "Argonaut." It had been a good deal of a mystery to us how workmen penned up in a submarine boat could expect to recover gold from wrecks in the water outside, or to place torpedoes, or to pick up cables, or to catch fish and clams as the crew of the "Argonaut" often had done.

"We simply open the door, and the diver walks out on the bottom of the sea," Mr. Lake said, quite as if he was conveying the most ordinary information.

At first it seemed incredible; but Mr. Lake showed us the heavily riveted door in the bottom of the diver's little room. Then he invited us inside with Wilson, who, besides being an engineer, is also an expert diver. The massive steel doors of the room were closed and barred, and then Mr. Lake turned a cock, and the air rushed in under high pressure. At once our ears began to throb, and it seemed as if the ear-drums would burst inward.

"Keep swallowing," said Wilson, the diver.

As soon as we applied this remedy the pain in our ears was relieved; but the general sensation of increased air pressure, while exhilarating, was still most uncomfortable. The finger on the pressure dial kept creeping up and up, until it showed that the air pressure inside of the compartment was nearly equal to the water pressure without. Then Wilson opened a cock in the door. Instantly the water gushed in, and for a single instant we expected to be drowned there like rats in a trap.

"This is really very simple," Mr. Lake was saying calmly; "when the pressure of the air within is the same as that of the water without, no water can enter."

With that Wilson dropped the iron door, and there lay the muddy bottom of the sea within touch of a man's hand. It was all easy enough to understand, and yet it seemed impossible, even as we saw it with our own eyes.

Mr. Lake stooped down and picked up a wooden rod having a sharp hook at the end. This he pulled along the bottom.

"You see how easily we can pick up a cable and cut it," he said. "Why, the New York telegraph cables, the most important in the world, are all within a few miles of this spot. The mine wires during the war were near here.

DIVER LEAVING THE "ARGONAUT" UNDER WATER.

The compartment from which the divers descend is heavily charged with compressed air to prevent the water from entering when the door is opened into the sea, the pressure being increased one atmosphere, or fifteen pounds, to the square inch for every thirty-five feet of descent below the surface.

CUTTING A CABLE BROUGHT UP THROUGH THE DOOR OF THE DIVER'S COMPARTMENT.

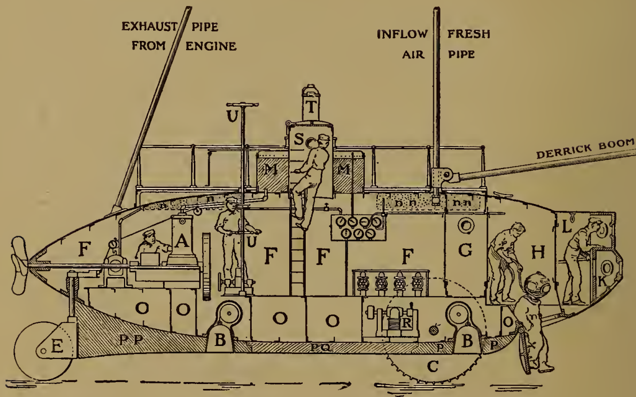
From a photograph.

We could have crawled along and cut every one of them, and no one ever would have been the wiser. More than that, if the 'Argonaut' had been at Santiago, we could have cleared the harbor of Spanish mines within forty-eight hours without the possibility of discovery. And after that"—Mr. Lake grew enthusiastic —"we could have crept along until we were just under one of the Spanish ships. Then our divers would have stepped out and deliberately set mines or even fastened torpedoes to the bottoms of the ships. When the work was done, we could have backed away, playing out our wires, until we were well out of reach of the effects of an explosion. And then, a connection of wires, and Sampson would have been saved the trouble of smashing Cervera."

Indeed, it seemed the simplest thing in the world.

"All you have to do when you want a good mess of oysters or clams," Wilson put in, "is to reach down and pick 'em."

"Yes," added Mr. Lake, "the 'Argonaut' or a boat like it will some day be the means of helping science to a much better knowledge of the wonders of the bottom of the sea. Think what treasures a scientist could get as the 'Argonaut' crawled slowly along the bottom with this door open."



LONGITUDINAL SECTION OF THE LAKE SUBMARINE BOAT "ARGONAUT."

A, gasolene engine, thirty horse-power, which supplies all the power used in moving and operating the boat. BB, the two anchor weights used in sinking the boat. C, one of the two driving wheels. E, rudder and guiding wheel. FFFF, the "living-room," in which are placed the engine and all the other machinery and apparatus for operating the boat. G, the air-lock: it affords passage to and from the diver's room without reducing the air-pressure. H, the diver's room, whence free passage is secured into the sea. K, bow compartment where the search-light is placed. L, the forward lookout compartment. MM, gasolene tanks. NN, compressed-air reservoirs. OOOO, water-ballast compartments. PP, permanent keel. PQ, drop keel. R, dynamo. S, conning-tower. T, binnacle. The compass in this binnacle is in direct view from the outside steering gear; but from the conning-tower it is read by reflection. U, outside steering gear. In general form the "Argonaut" is cylindrical, or cigar-shaped, with a very bluff bow and a pointed stern, and is thirty-six feet long.

But the "Argonaut's" most serious work is in wrecking. Mr. Lake explained how difficult it was for divers to go down to wrecks from the surface, owing to the great weight of air-tubing and life-lines, and how, if the water was at all rough, the attendants' boat usually bobbed up and down so violently that it became dangerous for a diver to remain below.

THE "ARGONAUT" IN THE PEARL, SPONGE, OR CORAL FISHERIES.

In the old way the divers could stay under water only for a minute or a minute and a half at the most, during which time they had to go up and down perhaps fifty or sixty feet, thus giving them opportunity at the bottom to make only a hasty exploration, and perhaps get a shell or two. The submarine vessel could wheel along over the bottom, and the pearl shells, coral, or sponges could be recovered through the open door, or divers could be sent out in their armor to search the bottom for a hundred feet on either side of the vessel.

$3,000. A little later he reduced the cost to $500 a pint, and the whole scientific world rang with the achievement.

When I visited Mr. Tripler's laboratory I saw five gallons of liquid air poured out like so much water. It was made at the rate of fifty gallons a day, and it cost, perhaps, twenty cents a gallon. Not long ago Mr. Tripler performed some of his experiments before a meeting of distinguished scientists at the American Museum of Natural History. It so happened that among those present was M. Pictet, the "father of liquid air." When he saw the prodigal way in which Mr. Tripler poured out the precious liquid, he rose solemnly and shook Mr. Tripler's hand. "It is a grand exhibition," he exclaimed in French; "the grandest exhibition I ever have seen."

The principle involved in air liquefaction is exceedingly simple, although its application has sorely puzzled more than one wise man. When air is compressed it gives out its heat. Any one who has inflated a bicycle tire has felt the pump grow warm under his hand. When the pressure is removed and the gas expands, it must take back from somewhere the heat which it gave out. That is, it must produce cold.

Professor Dewar applied this simple principle in all his experiments. He compressed

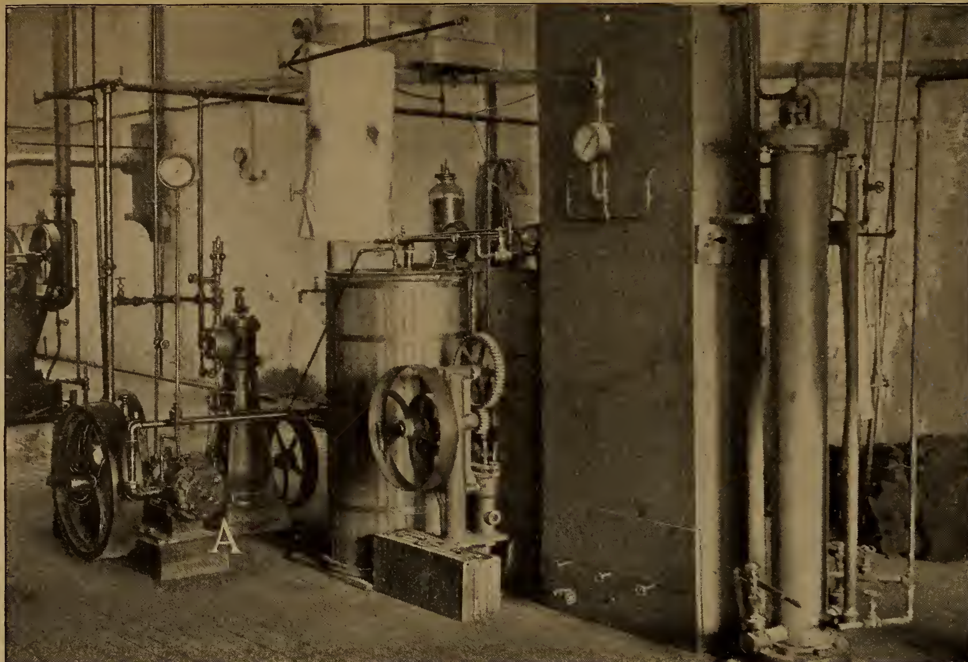
nitrous oxide gas and ethylene gas, and by expanding them suddenly in a specially constructed apparatus he produced a degree of cold which liquefied air almost instantly.

But nitrous oxide and ethylene are exceedingly expensive and dangerous, so that the product which Professor Dewar drew off was worth more than its weight in gold.

At the earliest announcement of the liquefaction of air Mr. Tripler had seen, with the quick imagination of the inventor, its tremendous possibilities as a power-generator, and he began his experiments immediately. After futile attempts to utilize various gases for the production of the necessary cold, it suddenly occurred to Mr. Tripler that air also was a gas. Why not use it for producing cold?

"The idea was so foolishly simple that I could hardly bring myself to try it," he told me, "but I finally fitted up an apparatus, turned on my air and drew it out a liquid."

Mr. Tripler's work-room has more the appearance of a machine shop than a laboratory. It is big and airy, and filled with the busy litter of the inventor. The huge steam boiler and compressor engine in one end of the room strike one at first as oddly disproportionate in size to the other machinery. Apparently there is nothing for all this power—it is a seventy-



SOME OF THE MACHINERY USED BY MR. TRIPLER FOR MAKING LIQUID AIR.

five horse-power plant—to work upon; it is hard to realize that the engine is drawing its raw material from the very room in which we are walking and breathing. Indeed, the apparatus where the air is actually liquefied is nothing but a felt and canvas-covered tube about as large around as a small barrel and perhaps fifteen feet high. The lower end is set the height of a man's shoulders above the floor, and there is a little spout below, from which, upon opening a frosty valve, the liquid air may be seen bursting out through a cloud of icy mist. I asked the old engineer who has been with Mr. Tripler for years, what was inside this mysterious swathed tube.

"It's full of pipes," he said.

I asked Mr. Tripler the same question.

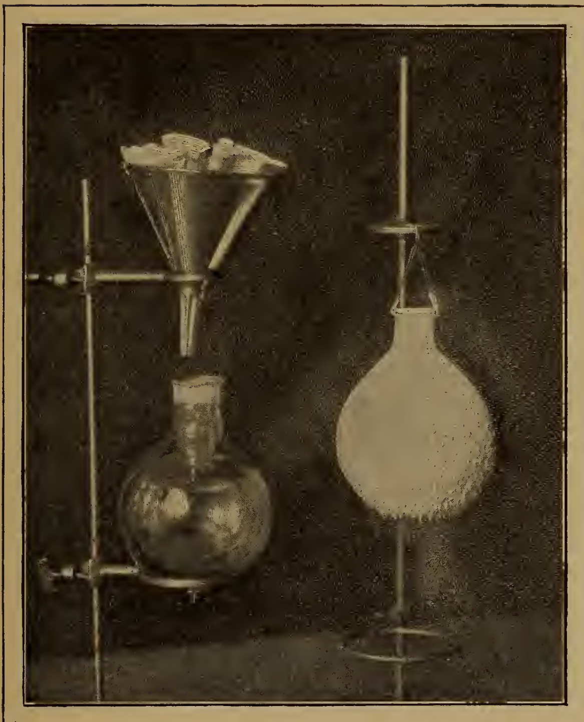
"Pipes," was his answer—"pipes and coils with especially constructed valves—that's all there is to it."

So I investigated the pipes. Two sets led back to the compressor engine, and Mr. Tripler explained that they both carried air under a pressure of about 2,500 pounds to the square inch. The heat caused by the compression had been removed by passing the pipes through coolers filled with running water, so that the air entered the liquefier at a temperature of about fifty degrees Fahrenheit.

"One of these pipes contains the air to be liquefied," explained Mr. Tripler; "the other carries the air which is to do the liquefying. By turning this valve at the bottom of the apparatus, I allow the air to escape through a small hole in the second pipe. It rushes out over the first pipe, expanding rapidly, and taking up heat. This process continues until such a degree of cold prevails in the first pipe that the air is liquefied and drips down into a small receptacle at the bottom. Then all I have to do is to turn a valve and the liquid air pours out, ready for use."

Mr. Tripler says that it takes only fifteen or twenty minutes to get liquid air after the compressor engine begins to run. Professor Dewar always lost ninety per cent. in drawing off his product; Mr. Tripler's loss is inappreciable.

Sometimes the cold in the liquefier becomes so intense that the liquid air actually freezes hard, stopping the pipes. Wonderful as it is to see ice that is made of air, it is not so wonderful as Mr. Tripler's story of the significance of this phenomenon. He tells how at some remote age in the future, all of the atmosphere which we now breathe will fall in drops of liquid, just such as he produces in his laboratory, and great lakes and oceans of air will



FILTERED LIQUID AIR IN A DEWAR BULB, AND LIQUID AIR IN AN ORDINARY GLASS BULB.

The Dewar bulb is composed of two bulbs with a vacuum between, which prevents the passage of heat, thereby protecting the liquid air so that it vaporizes very slowly. The other bulb, not so protected, has collected a shaggy coating of frost.

form on the earth, much resembling the present lakes and oceans of water.

"When the earth grows so cold that the air is liquefied," said Mr. Tripler, "of course all

the water on the earth will long ago have been frozen solid. Indeed, it will be as hard as rock crystal, and not unlike that substance in color and texture. After the air is all in the form of lakes or oceans, the cold will continue to increase until they in turn are frozen hard. After that the hydrogen, helium, and possibly some other very light gases, of which we may now have little knowledge, will fall in the form of rain, and then the world will be absolutely dead and inert, frozen as hard as the moon."

This entire process of the universe is typified in Mr. Tripler's laboratory, where every degree of temperature, from the heat of a steam boiler nearly down to the cold of interstellar space, can be produced at any time.

"When you come to think of it," says Mr. Tripler, "we're a good deal nearer the cold end of the thermometer than we are to the hot end. I suppose that once the earth had a temperature equal to that of the sun, say, 10,000 degrees Fahrenheit. It has fallen to an average of about sixty degrees in this latitude; that is, it has lost 9,940 degrees. We don't yet know just how cold the absolute cold really is—the final cold, the cold of interstellar space—but Professor Dewar thinks it is about 461 degrees below zero, Fahrenheit. If it is, we have only a matter of 521 degrees yet to

MR. TRIPLER ALLOWING THE LIQUID AIR TO FLOW FROM THE LIQUEFIER.

On striking the warm outer atmosphere, part of the liquid air instantly vaporizes, and flows out upon the floor in thick, billowy clouds.

lose, which is small compared with 9,940. Still, I don't think we have any cause to worry; it may take a few billion years for the world to reach absolute cold."

Mr. Tripler handles his liquid air with a freedom that is awe-inspiring. He uses a battered saucepan in which to draw it out of the liquefier, and he keeps it in a double iron can, not unlike an ice-cream freezer, covering the top with a wad of coarse felt to keep out as much heat as possible.

"You can handle liquid air with perfect safety," he said; "you can do almost anything with it that you can do with water, except to shut it up tight."

This is not at all surprising when one remembers that a single cubic foot of liquid air contains 748 cubic feet of air at ordinary pressure—a whole hall-bedroom full, reduced to the space of a large pail. Its desire to expand, therefore, is something quite irrepressible. But so long as it is left open it simmers contentedly for hours, finally disappearing whence it came. There being no way to confine liquid air in any considerable quantity, its transportation for long distances is therefore an unsolved problem, although Mr. Tripler has sent large cans of it to Boston, Washington, and Philadelphia.

"It is my belief," comments Mr. Tripler,

POSSIBLE METHOD OF CAUTERIZATION WITH LIQUID AIR.

"that there will be little need of transporting it; it can be made quickly and cheaply anywhere on earth."

Liquid air has many curious properties. It is nearly as heavy as water and quite as clear and limpid, although when seen in the open air it is always muffled in the dense white mist of evaporation which wells up over the edge of the receptacle in which it stands and rolls out

LIQUID AIR BOILING ON A BLOCK OF ICE.

Compared with liquid air, the temperature of which is 312° below zero, ice at 32° F. is as hot as a furnace, and it produces the same effect on liquid air that a hot fire would on water. The teapot is covered with white frost: moisture congealed from the atmosphere.

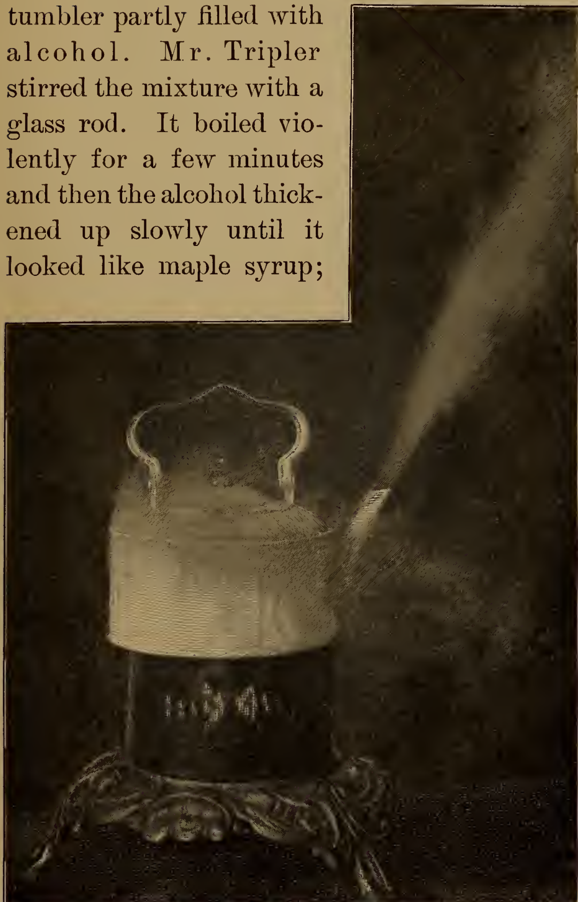
along the floor in beautiful billowy clouds. No other substance in the world, unless it be liquid hydrogen, is as cold as liquid air, and yet Mr. Tripler dips his hand fearlessly into a pail of liquid air, but he is careful to withdraw it instantly. The reason that it does not freeze him at once is the same that enables the workman to dip his hand into molten lead, the moisture of the human flesh forming a little cushion

of vapor which keeps away for a second the effect of the cold or the heat. A few drops held in my hand for an instant felt exactly like a red-hot coal. It does not really burn, of course, but it kills, leaving a little red blister not unlike a burn. For this reason, one of its prospective uses will be for the purpose of cauterization in surgical cases. It is not only a good deal cheaper than the ordinary caustics, but is much more efficient, and its action can be absolutely controlled. Indeed, a well-known surgeon performed a difficult operation on a cancer case with liquid air furnished by Mr. Tripler, and reported the case to be absolutely cured.

It is a curious thing to see liquid air placed in a teapot boiling vigorously on a block of ice, but it must be remembered that ice is nearly as much warmer than liquid air as a stove is warmer than water, so that it makes liquid air boil just as the stove makes water boil. If this same teapot is placed over a gas flame, a thick coating of ice will at once collect on the bottom between the kettle and the blaze, and no amount of heat seems enough to melt it.

Alcohol freezes at so low a temperature—202 degrees below zero—that it has been used in thermometers to register all degrees of cold. But it will not measure the fearful cold of liquid

air. I saw a cup of liquid air poured into a tumbler partly filled with alcohol. Mr. Tripler stirred the mixture with a glass rod. It boiled violently for a few minutes and then the alcohol thickened up slowly until it looked like maple syrup;



LIQUID AIR OVER FIRE.

Liquid air is so cold that when placed over a hot gas-stove, frost not only coats the entire receptacle in which it is contained, but a thick plating of ice gathers on the bottom directly over the blaze.

AN ICICLE OF FROZEN ALCOHOL.

An alcohol thermometer is supposed to measure all degrees of cold, but liquid air freezes alcohol in a few seconds to a hard lump of ice.

then it froze solid, and Mr. Tripler held it up in a long steaming icicle. Mercury is frozen in liquid air until it is as hard as granite. Mr. Tripler made a little pasteboard box the shape of a hammer-head, filled it with mercury, suspended a rod in it for a handle, and then placed it in a pan of liquid air. In a few minutes the mercury was frozen so solid

HANGING FROM A BLOCK OF FROZEN MERCURY.

The mercury is poured into a paper mold having a screw-eye inserted in each end. The mold is then placed in a basin of liquid air, where the mercury is quickly frozen solid. Suspended in the manner shown, the mercury block will support several hundred pounds for half an hour.

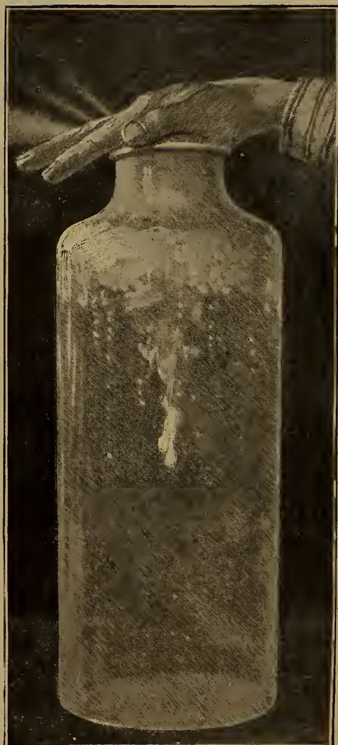
that it could be used for driving nails into a hard-wood block. What would the scientists of twenty-five years ago have said if any one had predicted the use of a mercury hammer for driving nails?

Liquid air freezes other metals just as thoroughly as it freezes mercury. Iron and steel become as brittle as glass. A tin cup which

DRIVING A NAIL WITH A HAMMER MADE OF MERCURY FROZEN BY LIQUID AIR.

has been filled with liquid air for a few minutes will, if dropped, shatter into a hundred little fragments like thin glass. Copper, gold, and all precious metals, on the other hand, are made more pliable, so that even a thick piece can be bent readily between the fingers.

Not long ago Mr. Tripler took a can of liquid air to the Harlem River, and poured it out on



LIQUID AIR IN WATER.

Liquid air is slightly lighter than water. When a small quantity of it is poured into a tall flask of water, it floats for a few seconds; and then the nitrogen boils away, leaving the liquid oxygen, which, being slightly heavier than water, sinks in big silvery bubbles.

the water in order to see its effect. Small masses of it at once collected in little round balls on the surface of the river, and being so much colder than the water, they froze small cups or boats of ice, in which they began floating about swiftly, bumping up against one another like so many lively water bugs, finally boiling away and disappearing, leaving the miniature ice boats quite still. If a small quantity of liquid air is placed in a tall jár of water, part of the liquid nitrogen, which is lighter than water, will evaporate first, then the liquid oxygen, which is

slightly heavier than the water, will sink in beautiful silvery bubbles.

I saw an egg frozen in liquid air. It came out so hard that it took a sharp blow of the hammer to crack it, and the inside of it had the peculiar crystalline appearance of quartz—a kind of mineral egg. At one time in Boston, Mr. Tripler had some of his liquid air with him at a hotel, where he was explaining its wonders to a party of friends. The waiter served a fine beefsteak for dinner, and Mr. Tripler promptly dipped it into the liquid air and then returned it with some show of indignation to the chef. It was as hard as rock crystal and when dropped on the floor it shivered into a thousand pieces.

"The time is certainly coming," says Mr. Tripler, "when every great packing house, every market, every hospital, every hotel, and many private houses will have plants for making liquid air. The machinery is not expensive, it can be set up in a tenth part of the space occupied by an ammonia ice machine, and its product can be easily handled and placed where it is most needed. Ten years from now hotel guests will call for cool rooms in summer with as much certainty of getting them as they now call for warm rooms in winter.

"And think of what unspeakable value the

liquid air will be in hospitals. In the first place, it is absolutely pure air; in the second place the proportion of oxygen is very large, so that it is vitalizing air. Why, it will not be necessary for the tired-out man of the future to make his usual summer trip to the mountains. He can have his ozone and his cool heights served to him in his room. Cold is always a disinfectant; some disease germs, like yellow fever, it kills outright. Think of the value of a 'cold ward' in a hospital, where the air could be kept absolutely fresh, and where nurses and friends could visit the patient without fear of infection!"

The property of liquid oxygen to promote rapid combustion will make it invaluable, Mr. Tripler thinks, for use as an explosive. A bit of oily waste, soaked in liquid air, was placed inside of a small iron tube, open at both ends. This was laid inside of a larger and stronger pipe, also open at both ends. When the waste was ignited by a fuse, the explosion was so terrific that it not only blew the smaller tube to pieces, but it burst a great hole in the outer tube. Mr. Tripler thinks that by the proper mixture of liquid air with cotton, wool, glycerine, or any other hydrocarbon, an explosive of enormous power could be produced. And unlike dynamite or nitro-glycerine, it could be

handled like so much sand, there being not the slightest danger of explosion from concussion, although, of course, it would have to be kept away from fire. It will take many careful experiments to ascertain the best method for making this new explosive, but think of the reward for its successful application! The expense of heavy ammunition and its difficult transportation and storage would be entirely done away with. No more would warships be loaded down with cumbersome explosives, and no more could there be terrible powder explosions on shipboard, because the ammunition could be made for the guns as it was needed, a plant on shipboard furnishing the necessary liquid air.

IRON AND COPPER TUBES BURST BY EXPLOSION OF LIQUID AIR WITH OILY WASTE.

Liquid air, owing to the large amount of

BURNING STEEL IN AN ICE TUMBLER PARTLY FILLED WITH LIQUID AIR.

A point of interest in this experiment is the contrasts in temperatures; steel is burning at 3,500° F. in an ice receptacle containing liquid air at 312° below zero.

oxygen which it contains, will make steel burn violently. Mr. Tripler places a little of it in a tumbler made of ice, and then thrusts into it a

steel spring having at the end a lighted match. The moment the steel strikes the liquid air it burns like a splinter of fat pine. This experiment shows a most astonishing range of temperature. Here is steel burning at 3,500 degrees above zero in an ice receptacle containing liquid air at 312 degrees below zero.

But all other uses of liquid air fade into insignificance when compared with the possibility of its utilization as power for running machinery, which is Mr. Tripler's chief object. I saw Mr. Tripler admit a quart or more of the liquid air into a small engine. A few seconds later the piston began to pump vigorously, driving the fly-wheel as if under a heavy head of steam. The liquid air had not been forced into the engine under pressure, and there was no perceptible heat under the boiler; indeed, the tube which passed for a boiler was soon shaggy with white frost. Yet the little engine stood there in the middle of the room, running apparently without motive power, making no noise and giving out no heat and no smoke, and producing no ashes. And that is something that can be seen nowhere else in the world.

"If I can make little engines run by this power, why not big ones?" asks Mr. Tripler.

"And run them entirely with air?"

"Yes, with liquid air in place of the water now used in steam boilers, and the ordinary heat of the air instead of the coal under the boilers. Air is the cheapest material in the world, but we have only begun learning how to use it. We know a little about compressed and liquid air, but almost nothing about utilizing the heat of the air. Coal is only the sun's energy stored up. What I do is to use the sun's energy direct.

"It is really one of the simplest things in the world," Mr. Tripler continued, "when you understand it. In the case of a steam-engine you have water and coal. You must take heat enough out of the coal, and put it into the water to change the water into a gas—that is, steam. The expansion of this gas produces power. And the water will not give off any steam until it has reached the boiling point of 212 degrees Fahrenheit.

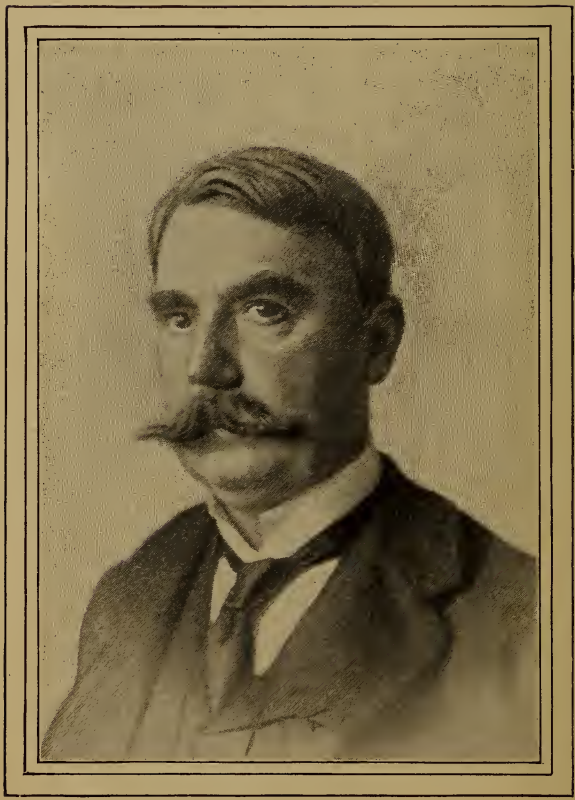
"Now steam bears the same relation to water that air does to liquid air. Air is a liquid at 312 degrees below zero—a degree of cold that we can hardly imagine. If you raise it above 312 degrees below zero it boils, just as water boils above 212 degrees. Now, then, we live at a temperature averaging, say, seventy degrees above zero—about the present temperature of this room. In other words,

RUNNING AN ENGINE WITH LIQUID AIR.

we are 382 degrees warmer than liquid air. Therefore, compared with the cold of liquid air we are living in a furnace. A race of people who could live at 312 degrees below zero would shrivel up as quickly in this room as we would if we were shut up in a baking oven. Now then, you have liquid air—a liquid at 312 degrees below zero. You expose it to the heat of this furnace in which we live, and it boils instantly and throws off a vapor which expands and produces power. That's simple, isn't it ?"

It did seem simple; and you remember with admiration that Mr. Tripler is the first man who ever ran an engine with liquid air, as he was also the first to invent a machine for making liquid air in quantities, a machine which has since been patented.

In some respects liquid air possesses a vast supremacy over steam. In the first place, it has about one hundred times the expansive power of steam. In the second place, it begins to produce power the instant it is exposed to the atmosphere. In making steam, water has first to be raised to a temperature of 212 degrees Fahrenheit. That is, if the water as it enters the boiler has a temperature of 50 degrees, 162 degrees of heat must be put into it before it will yield a single pound of pressure.



CHARLES E. TRIPLER.

After that, every additional degree of heat produces one pound of pressure, whereas every degree of heat applied to liquid air gives about twenty pounds of pressure.

"Liquid air can be applied to any engine," says Mr. Tripler, "and used as easily and as safely as steam. You need no large boiler, no water, no coal, and you have no waste. The heat of the atmosphere, as I have said before, does all the work of expansion."

The advantages of compactness, and the ease with which liquid air can be made to produce power by the heat of the atmosphere, at once suggested its use in all kinds of motor vehicles, and a firm in Philadelphia is now making extensive experiments looking to its use. A satisfactory application may do away with the present huge, misshapen, machinery-laden automobiles, and make possible small, light, and inexpensive motors.

Mr. Tripler even predicts that by the agency of liquid air, practical aërial navigation can be assured. The problem which has hitherto defeated the purposes of aërial navigators has been the difficulty of producing a propelling machine sufficiently light and yet strong enough to keep the propeller in motion. Liquid air requires no boilers, no fuel, no smokestacks, and the machinery necessary to its use will be a mere feather's weight compared with the ordinary steam engine.

Much has yet to be done before liquid air becomes the revolutionizing power of which

Mr. Tripler has prophesied. It has many disadvantages as well as advantages, and it will undoubtedly take Mr. Tripler and other inventors many years to perfect the machines necessary for using it practically. It will probably be chiefly valuable in cases where a source of power must be produced at one place and used at another. This much, however, has been positively accomplished: A machine has been built which will make liquid air in large quantities at small expense, and an engine has been successfully run by liquid air. Other developments will undoubtedly come later.

SIGNOR MARCONI AND HIS EARLIER APPARATUS FOR TELEGRAPHING WITHOUT WIRES.

CHAPTER III.

TELEGRAPHING WITHOUT WIRES.

How Marconi Sends Messages Through Space.

Marconi was a mere boy when he first began to dream of the marvellous possibility of sending telegraph messages without wires. He was barely twenty-one, a shy, modest, beardless youth, when he went up to London from his quiet country home in Italy to tell the world about one of the greatest inventions of the century. A few months later this boy had set up his apparatus and was telegraphing all sorts of messages through the air, through walls, through houses and towns, through mountains, and even through the earth itself, and that with a mechanism hardly more complicated or expensive than a toy telephone. The present system of telegraphy by means of wires, the sending of long despatches over continents and under oceans, is quite wonderful enough in itself, but here was an inventor who did away entirely with wires and all other means of mechanical connection, and sent his

messages directly through space. It is for this that Marconi was famous the world over at twenty-five.

The young inventor is described as being tall and slender, and dark of complexion. Al though he bears an Italian name and was born in Bologna, Italy (in 1874), and educated at Bologna, Leghorn, and Florence, he is only half Italian, his mother being an English woman. He speaks English readily and fluently, and he appears to like London better than his native land. His first experiments were carried on in the fields of his father's estate, and consisted merely of tin boxes set up on poles of varying heights, one of which was connected with a crude transmitting machine, and the other with an equally crude receiver, which he himself had manufactured.

Before going into the details of Guglielmo, or William, Marconi's apparatus and telling more of his astonishing successes, it may be well to look somewhat into the theories on which he bases his work. It must be understood, however, that Marconi was not the first to suggest wireless telegraphy, nor to signal experimentally for short distances without wires; but he was the first to perfect a system and to put it into practical operation, and to him, therefore, belongs the laurels of the inven-

THE WIRELESS TELEGRAPH STATION AT POOLE, ENGLAND, SHOWING SENDING AND RECEIVING INSTRUMENTS. IN RIGHT-HAND CORNER IS THE COPPER REFLECTOR USED IN DIRECTING WAVES.

Drawn from a photograph.

tion. Our own Prof. S. F. B. Morse, the inventor of telegraphy, experimented with wireless signals, and so did Dr. Oliver Lodge and W. H. Preece of London, Thomas A. Edison, Nikola Tesla, Professor Trowbridge of Harvard, and others.

In sending messages through space, Marconi deals with that mysterious all-pervading substance known as the ether. In the English language the word "ether" has two totally different meanings. It is the name of a clear, colorless liquid, which is used in surgical operations for easing a patient of pain. Every one has heard of "taking ether." This liquid, however, has nothing to do with the present subject, and it should be entirely dismissed from the mind. The ether which carries Marconi's messages is a colorless, odorless, unseen, inconceivably rarefied substance which is supposed to fill all space. Scientists know almost nothing as to its properties, but they do know that it will vibrate, and they have called these vibrations electricity, heat, and light.

It seems strange enough that we should use the ether every time we build a fire under the tea-kettle, every time we read by the light of a gas-jet, every time we talk over the telephone, and yet know next to nothing about it.

Throw a stone into a pond and you will pro-

duce a series of small waves or ripples—in other words, water vibrations. Strike a bell and vibrations in the air bring the sound to your ear. In a similar way ether has its own peculiar vibrations. For instance, a star millions of miles away starts the enormously rapid vibrations of light, and these vibrations finally reach our eyes, as the ripples in a pond reach the shore. We do not really see the star; we are merely conscious of light waves in the ether. In the same manner ethereal vibrations bring us the heat and light of the sun, and the awful energy of the lightning stroke. From this we know that the ether extends everywhere through space, and that the sun and the earth and the stars are set in it, like cherries in a jelly. Light will pass through such a hard, brittle substance as glass, heat will go through iron, and electricity "flows" in a copper wire. These facts show us that the ether must be inside of the glass and the iron and the copper, else the vibrations would not go through. In the same way the air is full of ether, and so are our bodies and everything else, for science knows nothing which entirely resists the passage of heat, light, and electricity. We call some substances solids, owing to their hardness, but so far as the ether is concerned there is no such thing as a

THE ROYAL YACHT "OSBORNE," FROM WHICH THE PRINCE OF WALES TELEGRAPHED WITHOUT WIRES.

The sending and receiving wire is suspended from the rope connecting the two mast-heads, and can be distinguished by the wire cone near the top. From a photograph by A. E. Beken.

solid. Every atom, even of the hardest diamond, is afloat in ether.

But if heat, light, and electricity are all caused by ether waves, how can we tell them apart?

The larger the stone you throw into the pond the larger the waves produced and the more rapidly they travel. In a similar way ether waves are of widely different lengths and rapidity or frequency. Vibrations of one speed give light, another speed give heat, and still another give electricity. Science has learned by a series of wonderful experiments that if the ether vibrates at the inconceivable swiftness of 400 trillions of waves every second, we see the color red, if twice as fast we see violet. If more slowly, from 200 to 400 trillions to the second, we experience the sensation of heat. If more rapidly than violet, we have what science knows as "unseen light"—the actinic rays and, probably, X-rays. Our eyes will take in only seven colors with vibrations from 400 to 800 trillions a second. If our eyes were better we might see other degrees of vibrations, such as X-rays and various electrical currents, and know new colors, stranger and more beautiful, perhaps, than any that we now see.

Ether waves should not be confused with air

waves. Sound is a result of the vibration of the air; if we had ether and no air we should still see and feel heat and electricity, but there would be nothing to hear. Air or sound waves are very slow compared with ether waves. A man's ordinary voice produces only about 130 waves a second, a woman's shrill scream will reach 2,000 vibrations—a mere nothing compared with the hundreds of trillions which represent light. Nor do air waves travel as rapidly as ether waves. In a storm the ether brings the flash of the lightning long before the air brings the sound of thunder, as every one knows.

Now, to get down to electricity. Certain vibrations of the ether are recognized as electricity—and there are many kinds of electrical waves to correspond with different degrees of vibration. Inventors have been able to utilize electricity by producing these ether waves by artificial means. I have compared the ether to a jelly. The electrician merely jars this jelly, and the vibrations which we know as a "current" are produced. A current does not really pass through a telegraph wire—it does not flow like water in a pipe,—although our common language has no other means of expressing its passage. In reality a vibration is started at one end of the wire, and it is the

MAST AND STATION AT SOUTH FORELAND, NEAR DOVER, ENGLAND, USED BY MARCONI IN TELEGRAPHING WITHOUT WIRES ACROSS THE CHANNEL TO BOULOGNE, FRANCE.

wave that travels. Set up a row of toy blocks. Tip over the first one, and it will tip over the second, and so on to the end. The blocks stay where they are, but the motion or

THE GOODWIN SANDS LIGHTSHIP.

Struck in a collision on April 28, 1899, the lightship used her Marconi apparatus (shown suspended by a spar from the masthead), and so got help from shore, twelve miles away.

wave goes onward to the end. An electric wave is, of course, invisible. Imagine a cork on the surface of a pond at any distance from the place where a stone is dropped; the cork,

when the wave reaches it, will bob up and down. Now, though we cannot see the electric wave, we can devise an arrangement which indicates the presence of the wave exactly after the manner of a cork.

Electric waves were discovered in 1842 by Joseph Henry, an American. He did not use the phrase "electric waves"; but he discovered that when he produced an electric spark an inch long in a room at the top of his house, electrical action was instantly set up in another wire circuit in his cellar. There was no visible means of communication between the two circuits, and after studying the matter he saw and announced that the electric spark set up some kind of an action in the ether, which passed through two floors and ceilings, each fourteen inches thick, and caused "induction"—set up what is called an induced current—in the wires in the cellar. This fact of induction is now one of the simplest and most commonplace phenomena in the work of electricians. Edison has already used it in telegraphing from a flying train. Hertz, the great German investigator, developed the study of these waves, and announced that they penetrated wood and brick, but not metal. The "Hertzian wave" is, indeed, an important feature of wireless telegraphy. Strange to say, however, considering

Marconi.

WILLIAM MARCONI AND HIS ASSISTANT, A. E. BULLOCKE.

the number of brilliant electricians in the world, and the great interest in electrical phenomena, it was left to the young Italian, Marconi, to frame the largest conception of what might be done with electric waves, and to invent instruments for doing it.

Marconi's reasoning was exceedingly simple. The ether is everywhere; it is in the air and in the mountains and in houses as well as in a copper wire. Electricity must, therefore, pass through the air and the mountain as well as through the wire. The difficulty lay in making an apparatus that would produce a peculiar kind of wave, and to catch or receive this wave in a second apparatus located at a distance from the first. This he finally succeeded in doing by the use of waves similar to those produced by Hertz, which he excited in a specially constructed apparatus. These waves have a frequency of about 250 millions every second. From the generating apparatus this peculiar current is communicated to a wire which hangs from the top of a long pole or mast, or from a kite, and it passes by induction, through miles of air and earth and buildings, to a second hanging wire, which conveys it to a receiving instrument, where the signals are registered. To understand this transfer we must understand exactly what induction means. An elec-

trical current may be *conducted* through copper wire, water, iron, or any other good "conductor." In *induction* the current passes directly through the ether. When a current of electricity passes through a wire, magnetism is present around that wire; and if another wire be brought within the magnetic field of the charged wire and placed parallel with it, it will also become charged with electricity. That is *induction*, and it enables Marconi to send his messages across the Channel from England to France, from ships on the sea to shore, from light-house to light-house, and across wide stretches of open country.

And now, having come to an understanding of the theory of sending messages without wires, we may take a look at Marconi's actual apparatus as it is now transmitting messages from the Needles in Alum Bay, at the extreme west end of the Isle of Wight, eighteen miles across the Channel, to Poole on the mainland of England.

From the very peak of Marconi's telegraph mast at the Needles hangs a line of wire that runs through a window into the little sending-room. Here two matter-of-fact young men are at work as calmly as any ordinary telegraphers, talking through the ether. One of them has his fingers on a black-handled key. He is say-

SOUTH FORELAND, THE ENGLISH STATION FROM WHICH MESSAGES WERE SENT WITHOUT WIRES TO BOULOGNE, FRANCE, THIRTY-TWO MILES AWAY. THE MAST SUPPORTING THE VERTICAL WIRE IS SEEN ON THE EDGE OF THE CLIFF.

ing something to the Poole station eighteen miles away in England.

> "Brripp—brripp—brripp—brrrrrr.
> Brripp—brripp—brripp—brrrrrr—
> Brripp—brrrrrr—brripp. Brripp—brripp!"

So speaks the sender with noise and deliberation. It is the Morse code working—ordinary dots and dashes which can be made into letters and words, as everybody knows. With each movement of the key bluish sparks jump an inch between the two brass knobs of the induction coil, the same kind of coil and the same kind of sparks that are familiar in experiments with the Röntgen rays. For one dot, a single spark jumps; for one dash, there comes a stream of sparks. One knob of the induction coil is connected with the earth, the other with the wire hanging from the masthead. Each spark indicates a certain impulse from the electrical battery; each one of these impulses shoots through the wire, and from the wire through space by vibrations of the ether, travelling at the speed of light, or seven times around the earth in a second. That is all there is in the sending of these Marconi messages. Any person of fair intelligence could learn to do it, Morse code and all, in a few hours.

After sending a message the young opera-

tor switches on to the receiver, which is contained in a metal box about the size of a valise. The same perpendicular wire from the masthead serves to receive messages as well as to send them, but the instruments within the office for sending and for receiving are quite different.

The receiving apparatus is kept in a lead box to protect it against the influence of the sending machine, which rests beside it on the table. You can easily believe that a receiver, sensitive enough to record impulses from a point eighteen miles away, might be disorganized if these impulses came from a distance of two or three feet. But the lead box keeps out these nearby vibrations.

The coherer is the part of the receiving apparatus which makes wireless telegraphy possible, and to it more than to anything else has Marconi given his attention. He did not make the first coherer, but he made the first one that was practically useful, and to this great and important invention he owes his success.

I will try to give a clear idea of what this coherer is like, and why it is so important. It consists of a tube made of glass, about the thickness of a thermometer tube, and about two inches long. It seems absurd that so tiny and simple an affair can come as a benefit to all

mankind; yet the chief virtue of Marconi's invention lies here in this fragile coherer. But for this, induction coils would snap their messages in vain, for none could read them. In each end of this tube there is a silver plug, the two plugs nearly meeting within the tube. In the narrow space between the plugs nestle several hundred minute fragments of nickel and silver, the finest dust, siftings through silk, and these enjoy the strange property (as Marconi discovered) of being alternately very good conductors and very bad conductors for the Hertzian waves—very good conductors when welded together by the passing current into a continuous metal path, very bad conductors when they fall apart under a blow from the electrical tapper which is a part of the receiving apparatus. One end of the coherer is connected with the wire which hangs from the mast outside, the other with the earth and also with a home battery that works the tapper and the Morse printing instrument.

And the practical operation is this: A single vibration comes through the ether, down the wire and into the coherer, causing the particles of metal to stick together or *cohere* (hence the name). Then the Morse instrument prints a dot, and the tapper strikes its little hammer against the glass tube. That blow jars apart

or *decoheres* the particles of metal, and stops the current of the home battery. And each successive impulse through the ether produces the same curious coherence and decoherence, and the same printing of dot or dash. The impulses through the ether would never be strong enough of themselves to work the printing instrument and the tapper, but they are strong enough to open and close a valve (the metal dust), which lets in or shuts out the stronger current of the home battery—all of which is simple enough after some one has taught the world how to do it.

Mr. Cleveland Moffett, who has made a personal study of wireless telegraphy with Mr. Marconi and his assistant, Dr. Erskine-Murray, says that even the curvature of the earth itself seems to make no difference in the transmittal of messages.

"We have telegraphed twenty-five miles from a ship to the shore," Dr. Murray told Mr. Moffett, "and in that distance the earth's dip amounts to about 500 feet. If the curvature counted against us then, the messages would have passed some hundreds of feet over the receiving station; but nothing of the sort happened. So we feel reasonably confident that these Hertzian waves follow around smoothly as the earth curves."

THE APPARATUS EMPLOYED AT SOUTH FORELAND LIGHTHOUSE FOR COMMUNICATING WITH THE GOODWIN SANDS LIGHTSHIP AND WITH BOULOGNE.

Drawn from a photograph.

"And you can send messages through hills, can you not, and in all kinds of weather?"

"Easily. We have done so repeatedly."

"Then if neither land nor sea nor atmospheric conditions can stop you, I don't see why you can't send messages to any distance."

"So we can," said the electrician—"so we can, given a sufficient height of wire. It has become simply a question now how high a mast you are willing to erect. If you double the height of your mast, you can send a message four times as far. If you treble the height of your mast, you can send a message nine times as far, and so on up. To start with, you may assume that a wire suspended from an eighty-foot mast will send a message twenty miles. We are doing about that here."

"Then a mast 160 feet high would send a message eighty miles?"

"Exactly."

"And a mast 320 feet high would send a message 320 miles; a mast 640 feet high would send a message 1,280 miles; and a mast 1,280 feet high would send a message 5,120 miles?"

"That's right. So you see if there were another Eiffel Tower in New York, it would be possible to send messages to Paris through the ether and get answers without ocean cables."

"Do you really think that would be possible?"

"I see no reason to doubt it," answered Dr. Erskine-Murray. "What are a few thousand miles to this wonderful ether, which brings us our light every day from millions of miles away?"

One of the greatest of present difficulties is that of securing secrecy in the transmission of these ethereal messages. The vibrations from the perpendicular wires are transmitted equally well in every direction, exactly as circular waves are produced when a stone is thrown in the water. Therefore any one may set up a receiver anywhere within the range of the waves, and take the message. Thus, in times of war, communications between battleships or armies might be at the mercy of any one who had a Marconi receiver, although, of course, generals and admirals might use cipher despatches.

Marconi realizes the very great importance of sending messages in one and only one direction. Light waves can be reflected by a mirror, and thrown upon one particular spot. Every boy who has played in school with a bit of looking-glass knows this fact well. Now, electricity, which is also produced by vibrations in the ether, can also be reflected.

Marconi has been experimenting with a copper reflector, by means of which he throws a peculiar kind of electrical wave directly through space to the distant receiver. In this way a message may be aimed in any direction by simply turning the reflector a little, and no one but the man at the receiver can know what is being sent. This exceedingly important feature of the work is, however, still in an experimental stage, and the inventor who is successful in making a really practical reflecting apparatus will win a fortune.

The practical uses of wireless telegraphy are many. In December, 1898, the English lightship service authorized the establishment of wireless communication between the South Foreland lighthouse at Dover and the East Goodwin lightship, twelve miles distant. This was installed in the usual way without difficulty, and has been in operation ever since, the lightship keepers learning to use the instruments in a few days. And before the apparatus had been up six months several warnings of wrecks and vessels in distress reached shore, when, but for the Marconi signals, nothing of the danger would have been known.

Another application of wireless telegraphy that promises to become important is the signalling of incoming and outgoing vessels.

With Marconi stations all along the coast, it would be possible for all vessels within twenty-five miles of shore to make their presence known and to send or receive communications.

So apparent are the advantages of such a system that in May, 1898, Lloyds began negotiations with the Wireless Telegraph Company for setting up instruments at various Lloyds stations; and a preliminary trial was made between Bally-castle and Rathlin Island in the north of Ireland. The distance signalled was seven and a half miles, with a high cliff intervening between the two positions, and the results of many trials were absolutely satisfactory.

We come now to that historic week in March, 1899, when the system of wireless telegraphy was put to its most severe test in experiments across the English Channel between Dover and Boulogne. These were undertaken by request of the French Government, which was considering a purchase of the rights to the invention in France. At five o'clock on the afternoon of Monday, March 27th, everything being ready, Marconi pressed the sounding-key for the first cross-channel message. The transmitter sounded, the sparks flashed, and a dozen eyes looked out anxiously upon the sea. Would the message carry all the way

THE MAST AND STATION AT BOUOLGNE, FRANCE, USED BY MARCONI IN TELEGRAPHING WITHOUT WIRES ACROSS THE CHANNEL.

Drawn from a photograph.

to England? Thirty-two miles seemed a long way!

Marconi transmitted deliberately a short message, telling the Englishmen that he was using a two-centimetre spark, and signing three V's at the end. Then he stopped, and the room was silent with a straining of ears for some sound from the receiver. A moment's pause, and then it came briskly, and the tape rolled off its message. There it was, short and commonplace enough, yet vastly important, since it was the first wireless message sent from England to the Continent: First "V," the call; then "M," meaning "Your message is perfect"; then, "Same here, 2 c m s. V V V.," the last being an abbreviation for two centimetres and the conventional finishing signal.

And so the thing was done; a marvellous new invention was come into the world to stay.

On the following Wednesday Marconi did a graceful thing by sending a complimentary message to M. Branly (in Paris), the inventor of the original coherer, which Marconi had improved upon. He also sent a long message to the Queen of Italy.

Mr. Moffett asked one of Marconi's chief engineers if there was not a great saving by the wireless system over cables.

"Judge for yourself," was the answer. "Every mile of deep-sea cable costs about $750; every mile for the land-ends about $1,000. We save all that, also the great expense of keeping a cable steamer constantly in commission making repairs and laying new lengths. All we need is a couple of masts and a little wire. The wear and tear is practically nothing. The cost of running is simply the cost of home batteries and operators' keep."

"How fast can you transmit messages?"

"Just now at the rate of about fifteen words a minute; but we shall do better than that, no doubt, with experience."

"Do you think there is much field for the Marconi system in overland transmission?"

"In certain cases, yes. For instance, where you can't get the right of way to put up wires and poles. What is a disobliging farmer going to do if you send messages right through his farm, barns and all? He can't sue the Hertzian waves for trespass, can he? Then see the advantage, in time of war, for quick communication, and no chance that the enemy may cut your wires."

"But they may read your messages."

"That is not so sure, for besides the possibility of directing the waves with reflectors, Marconi is now engaged in most promising ex-

periments in syntony, which I may describe as the electrical tuning of a particular transmitter to a particular receiver, so that the latter will respond to the former and no other, while the former will influence the latter and no other. That, of course, is a possibility in the future, but it may soon be realized. There are even some who maintain that there may be produced as many separate sets of transmitters and receivers capable of working together as there are separate sets of Yale locks and keys. In that event, any two private individuals might communicate freely without fear of being understood by others. There are possibilities here, granting a limitless number of distinct tunings for transmitter and receiver, that threaten our whole telephone system—I may add, our whole newspaper system."

"Our newspaper system?"

"Certainly, the news might be ticked off tapes every hour right into the houses of all subscribers who had receiving instruments tuned to a certain transmitter at the news-distributing station. Then the subscribers would have merely to glance over their tapes, and they would learn what was happening in the world."

"Will the wireless company sell its instruments?"

"No, it will rent them on a royalty, as telephone companies do, except, of course, where rights for a whole country are absolutely disposed of."

There was further talk of the possibilities in wireless telegraphy, and of the services Marconi's invention may render in coming wars.

"If you care to stray a little into the realm of speculation," said the engineer, "I will point out a rather sensational rôle that our instruments might play in military strategy. Suppose, for instance, you Americans were at war with Spain, and wished to keep close guard over Havana harbor without sending your fleet there. The thing might be done with a single fast cruiser in this way: Supposing a telegraphic cable laid from Key West, and ending at the bottom of the sea a few miles out from the harbor. And supposing a Marconi receiving instrument, properly protected, to be lying there at the bottom in connection with the cable. Now, it is plain that this receiver will be influenced in the usual way by a Marconi transmitter aboard the cruiser, for the Hertzian waves pass well enough through water. With this arrangement, the captain of your cruiser may now converse freely with the admiral of the fleet at Key West or with the President himself at Washington, without so

TRANSMITTING INSTRUMENT AT BOULOGNE STATION.

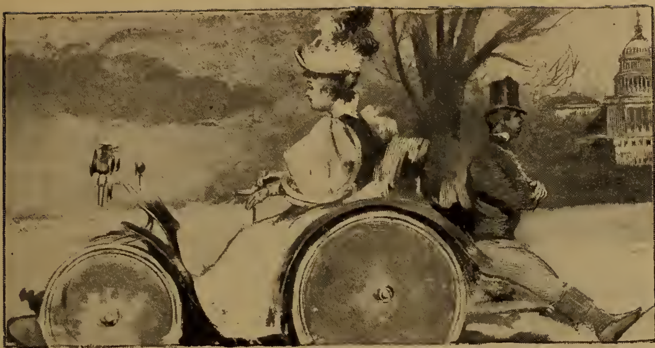
Drawn from a photograph.

much as quitting his deck. He may report every movement of the Spanish warships as they take place, even while he is following them or being pursued by them. So long as he keeps within twenty or thirty miles of the submerged cable-end, he may continue his communications, may tell of arrivals and departures, of sorties, of loading transports, of filling bunkers with coal, and a hundred other details of practical warfare. In short, this captain and his innocent-looking cruiser may become a never-closing eye for the distant American fleet. And it needs but little thought to see how easily an enemy at such disadvantage may be taken unawares or be led into betraying important plans."

And here, I think, we may leave this fascinating subject, in the hope that we have seen clearly what already is, and with a half discernment of what is yet to be.

M. JENATZY AND HIS "NEVER CONTENT," MAKING SIXTY-SIX MILES AN HOUR.

From instantaneous photographs appearing in "The Autocar."

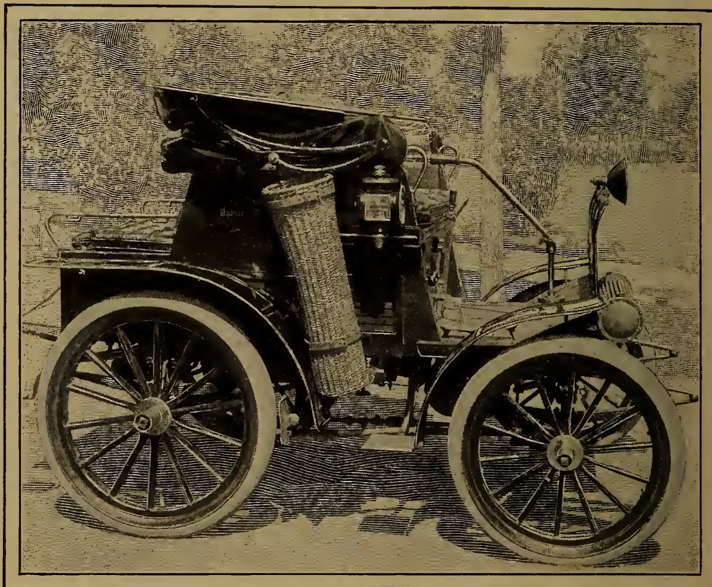


CHAPTER IV.

THE MODERN MOTOR VEHICLE.

Sixty-six Miles an Hour on an Ordinary Road.

Step up and take your seat in the world's very newest and most marvellous vehicle—the motor carriage. As you sit facing forward, where the horse ought to be and isn't, your right hand fits easily and naturally over the smooth handle of a lever. Press your thumb down hard on a little button at the top and a bell rings sharply—a mere friendly warning that you are about to start. Now push the lever forward one notch and off you go, smoothly and steadily, but slowly; another notch, and you are making the speed of a trotting horse; still another notch, and you are flying like the wind, far faster than any horse ever goes

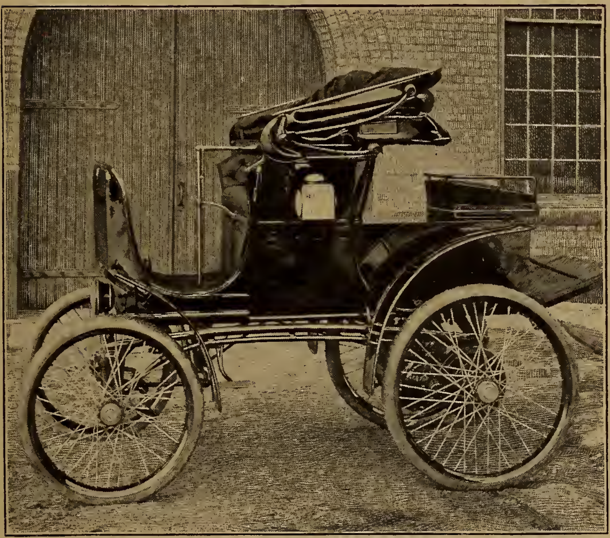


A FRENCH TOURING CART, DRIVEN BY GASOLENE.

under harness. While your right hand is thus employed with the speeding lever, your left is firmly holding the steering handle, swinging the vehicle, this way and that, around corners and past obstacles as easily as if it were a bicycle. If you wish to stop suddenly, your foot is on a brake; a slight push and the vehicle comes to a standstill.

Variations there are in the arrangement of levers and brakes in different vehicles, but

A MOTOR TALLY-HO, PROPELLED BY STORED ELECTRICITY.



A TYPICAL AMERICAN ELECTRIC CARRIAGE.

they are all equally simple of management. You can travel from daylight to dark and never suffer with a worn-out horse; you can run away from the dust and escape the flies, and if you reach a railroad crossing just as a train is passing, your motor carriage never takes fright and runs away. When you reach home there is no troublesome unharnessing, nor rubbing-down, and your carriage is ready at a second's notice to start on a new expedition. And as for the carriage-whip, it will follow the horse out of existence.

A LIGHT RUNABOUT, DRIVEN BY GASOLENE.

Only a few years ago, in 1894, there were not thirty of these remarkable vehicles in practical use in all the world. At the beginning of 1898 there were not thirty in all America. And yet so great was the success of the inventor, and so widespread the interest of the public, that the manufacture of motor vehicles suddenly became a great industry. In the first four months of the year 1899 alone, corporations with the enormous aggregate capitalization of more than $300,000,000 were organized in New York, Boston, Chicago, and Philadelphia; and

THE SERPOLLET STEAM CAB.

in many cities of the East motor vehicles have become so familiar on the streets that they are

MORRIS & SALVIN'S "ELECTROBAT."

From a photograph by Copelin, Chicago.

noticed hardly more than horse carriages. More than that, motor ambulances, motor trucks, motor gun-carriages, motor stages, and motor fire-engines are in operation in various cities.

A DAIMLER PETROLEUM-ENGINE CARRIAGE.

In France and England the motor vehicle has become an established and powerful factor in the common affairs of life. France has a powerful motor vehicle or "automobile" club which gives frequent races and exhibitions. At a sin-

THE SERPOLLET STEAM CARRIAGE.

gle gathering more than 1,500 vehicles were shown, representing every conceivable model,

DURYEA MOTOR WAGON, WINNER OF THE CHICAGO "TIMES-HERALD" RACE, NOVEMBER 28, 1895.

From a photograph, by permission of "The Horseless Age."

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from milk-wagons to fashionable broughams and the huge brakes of De Dion and Bouton, which carry almost as many passengers as a railroad car. Some of the expert "drivers" of Paris have ridden thousands of miles in their road wagons, have climbed mountains, and raced through half of Europe, meeting new accidents, facing new adventures, and using strange new devices for which names have yet to be coined.

The motor races of Paris have been by far the most unique and remarkable that the world has ever seen. Both M. Réne de Knyff and Count Chasseloup-Laubat, of Paris, have made 60 miles an hour on an ordinary road track. Just think of it! Faster than the Empire State Express, and that with no advantage of steel rails nor level road-bed. But even the records of these two famous racers have been beaten by M. Jenatzy with his lightning carriage, "La Jamais Contente" ("The Never Content"). This wonderful vehicle is built of sheet iron in the form of a long cigar or torpedo, so that it plunges through the air like a dart. The wheels are very small and, of course, fitted with rubber tires. There is a manhole in the top of the vehicle, where the driver sits. Just in front of it there is a little steering wheel and electrical meters to show the voltage and am-

AN ELECTRIC HANSOM CAB.

pèreage of the current. To see "La Jamais Contente" one would think that no driver ever would dare to risk his life upon it. And, indeed, after the current is turned on and the wheels begin to revolve, it is either fly or burn, so tremendous is the power of the batteries.

At the famous record trial "La Jamais Con-

tente" was towed out from Paris to the racing road by a humble petroleum car. M. Réne de Knyff gave the word to start. M. Jenatzy turned on the current and braced himself, leaning well forward, with his hands firmly clasping the steering wheel. The car moved off somewhat slowly at first, but after going about 10 yards, literally bounded forward, the wheels for a moment almost leaving the track. There was a blue-gray streak down the road, a faint cloud of dust, and the famous carriage was making more than a mile a minute. The sound of the motor was described by a spectator as resembling the rustling of wings, and the car undulated like a swallow in flying, this no doubt being due to the action of the springs and the rubber tires. Nothing had ever before travelled on a common road at such a speed, and the spectators were anxious to know, not whether Jenatzy had broken the record, but by how much he had broken it. The wheels left two broad white tracks in the middle of the road, absolutely straight and converging in the distance like a line of rails. It was a remarkable exhibition of accurate steering. Indeed, if Jenatzy had swerved an inch to the right or to the left, he would not have survived to tell the tale. After the trial was over it was found that "La Jamais Contente" had made 66 miles

FETCHING THE DOCTOR. ALREADY PHYSICIANS HAVE FOUND THE AUTOMOBILE OF SPECIAL SERVICE TO THEM.

an hour, and M. Jenatzy went away declaring that he should soon make 75 miles an hour.

In general it may be said that France has led in gasolene vehicles, and England in steam vehicles, while America, as was to be expected, has been far in the lead in electrical conveyances of all kinds. Belgium and Germany, and to some extent Austria, have also been experimenting with more or less success, but no such progress has been made in these countries as in France. It was not until 1898 that Spain rubbed its eyes for the first time at the sight of a motor vehicle, which rolled through Madrid with half a dozen little policemen careering after it.

In a general way, it may be said that the best modern motor vehicle, whatever its propelling power, is practically noiseless and odorless and nearly free from vibrations. It is still heavy and clumsy in appearance, although it is lighter than the present means of conveyance when the weight of the horse or horses is counted in with the carriage. And invention will soon lighten it still further. It cannot possibly explode. It will climb all ordinary hills, and on a level road it will give all speeds from two miles an hour up to twenty or more. Its mechanism has been made so simple that any one can learn to manage it in an hour or two.

And yet it is mechanism; and intelligence, coolness, and caution are required to manage a motor vehicle in a crowded street. The operator must combine the intelligence of the driver with that of the horse, and he does not appreciate the almost human sagacity of that despised animal until he has tried to steer a motor vehicle down Fifth Avenue on a sunny afternoon.

Seven different motive powers are now actually employed in this country: electricity, gasolene, steam, compressed air, carbonic-acid gas, alcohol, and liquid air. The first three of these have been practically applied with great success; all the others are more or less in the experimental stage.

The electric vehicle, which has had its most successful development in this country, has its well-defined advantages and disadvantages. It is simpler in construction and more easily managed than any other vehicle: one manufacturer calls it "fool proof." It is wholly without odor or vibrations and practically noiseless. It will make any permissible rate of speed, and climb any ordinary hill. On the other hand, it is immensely heavy, owing to the use of storage batteries; it can run only a limited distance without recharging, and it requires a moderately smooth road. In cost it is the most expensive of all vehicles. And yet for city use,

A DAIMLER MOTOR CARRIAGE NEAR FIFTH AVENUE AND FIFTY-EIGHTH STREET, NEW YORK.

where a constant supply of electricity can be had, electrical cabs, carriages, and delivery wagons have demonstrated their remarkable practicability.

The vital feature of the electric vehicle is the storage battery, which weighs from 500 to 1,500 pounds, the entire weight of the vehicles varying from about 900 to 4,000 pounds. A phaeton for ordinary private use will weigh upwards of a ton, with a battery of 900 pounds. This immense weight requires exceedingly rigid construction and high-grade, expensive tires. The electrical current is easily controlled by means of a lever under the hand of the driver, the propelling machinery being comparatively simple. When the battery is nearly empty, it may be recharged at any electric-lighting station by the insertion of a plug, the time required varying from two to three hours. Or, if the owner prefers, he can own his own charging plant and generate his own electricity: it will cost him from $500 to $700. The current not only operates the vehicle, but it lights the lamps, rings the gong, and in cabs and broughams actuates a push-button arrangement for communication between passenger and driver. The limit of travel without recharging is from 20 to 30 miles. A good electric carriage for family use cannot be obtained for

much less than $2,000, although one or two manufacturers advertise runabouts and buggies at from $750 to $1,500. An omnibus costs from $3,000 to $4,000.

The company which operates the electric cab system in New York has a most extensive charging plant. Two batteries are provided for each vehicle, so that, when one is empty, it may be removed by the huge fingers of a travelling crane, placed on a long table, and recharged at leisure, while a completely filled battery is introduced in its place. This change takes only a few minutes, and the cab can be used continuously day and night.

The "lightning cabby" is a product of the new industry. He wears a blue uniform somewhat resembling that of a fireman, and he is a cool-headed, intelligent fellow, who can make 10 miles an hour in a crowded street without once catching the suspicious eye of a policeman. Most of the "cabbies" have had previous experience as drivers, but they are given a very thorough training before they are allowed to venture on the streets with a vehicle of their own. A special instructor's cab is in use by the company. It has a flaring front platform with a solid wooden bumper, so that it may crash into a stone curb or run down a lamp-

MODELS OF THE MOTOR AMBULANCE, MOTOR TRICYCLE, AND MOTOR OMNIBUS NOW COMING INTO USE.

post without injury. The new man perches himself on the seat behind, and the instructor takes his place inside, where he is provided with a special arrangement for cutting off the current or applying the brakes, should the vehicle escape from the control of the learner. It usually takes a week to train a new man so that he can manage all the brakes and levers with perfect presence of mind. Both of his hands and both of his feet are fully employed. With his left hand he manages the power lever, pushing it forward one notch at a time to increase the speed. With his right hand he controls the steering lever, which, by the way, turns the rear wheels and not the front ones, as is done with horse-propelled vehicles. His left heel is on the emergency switch, and his left toe rings the gong. With his right heel he turns the reversing switch, and he may apply the brake with either his right or his left foot. When he wishes to turn on the lights, he presses a button under the edge of the seat. Hence, he is very fully employed, both mentally and physically. He can't go to sleep and let the old horse carry him home.

In France the system of instruction for drivers or *chauffeurs* (stokers), as they are called, is much more complicated and extensive, but hardly more thorough. There the

cab company has prepared a 700-yard course up hill and down, and paved it alternately with cobbles, asphalt, wooden blocks, and macadam, so as to give the incipient "cabby" experience in every difficulty which he will meet in the streets of Paris. Upon the inclines are placed numerous lay figures, made of iron—a typical Parisian nurse-maid with a bassinet, a bicycle rider; an old gentleman, presumably deaf, who is not spry in getting out of the way; a dog or two, and paper bricks galore. Down through this throng must the motorman thread his way and clang his gong, and he is not considered proficient until he can course the full length of the "Rue de Magdebourg," as the cabbies call it, without so much as overturning a single pastry cook's boy or crushing a dummy brick.

New York cabs will run 20 miles without recharging. But it is not at all infrequent for a new man to have his vehicle stop suddenly and most unexpectedly; the current deserts him before he knows it. He must let the central office know at once, and the ambulance cab comes spinning out, hooks to the helpless vehicle, and drags it into the charging station. The company expects soon to have ten charging stations in operation in various parts of the city, so that a cab will never have far to go for a new charge of electricity. Indeed, all the

THE TRAINING COURSE FOR AUTOMOBILE DRIVERS AT AUBERVILLIERS, NEAR PARIS.

The course, besides being obstructed by the dummy figures shown in the picture, is strewn with paper bricks, and thus becomes as severe a test as possible of the skill of the motorman.

manufacturers of electrical vehicles speak with confidence of the day when the whole of the United States will be as thoroughly sprinkled with electric charging stations as it is to-day with bicycle road-houses. One manufacturer has issued lists of hundreds of central stations throughout New England, New York, and other Eastern States where automobiles may be provided with power.

It is not hard to imagine what a country touring station will be like on a sunny summer afternoon some five or ten years hence. Long rows of vehicles will stand backed up comfortably to the charging bars, each with its electric plug filling the battery with power. The owners will be lolling at the tables on the verandas of the nearby road-house. Men with repair kits will bustle about tightening up a nut here, oiling this bearing, and regulating that gear. From a long rubber tube compressed air will be hissing into pneumatic tires. There will also be many gasolene carts and road wagons and tricycles, and they, too, will need repairs and pumping, and their owners will employ themselves busily in filling their little tin cans with gasolene, recharging their tanks, refilling the water-jackets, and looking to the working of their sparking devices. And then there will be boys selling peanuts, arnica, and

court-plasters, and undoubtedly a cynical old farmer or two with a pair of ambling mares to carry home such of these new-fangled vehicles as may become hopelessly indisposed. Add to this bustling assembly of amateur "self-propellers" a host of bicycle riders—for there will doubtless be as many bicycles in those days as ever—and it will be a sight to awaken every serious-minded horse to an uneasy consideration of his future.

Nor is this dream so far from being a picture of actual conditions. In Belgium a company has recently been formed to establish electric posting stations. Its promoters plan to have a bar and restaurant connected with the charging plant, a regular medical attendant, and an expert mechanic who will know how to remedy all the ills of motor vehicles. In the larger cities the time must soon come when there will be coin-in-the-slot "hydrants" for electricity at many public places, from which owners of vehicles may charge their batteries while they wait.

A number of prominent New York physicians own their own motor vehicles, these being especially adapted to the varied necessities of a physician's practice. A motor vehicle is always ready at a moment's notice—it does not have to be harnessed. It can work twenty-four

A MOTOR FIRE-ENGINE. THE LARGEST FIRE-ENGINE IN THE WORLD.

This self-propelling fire-engine is owned by the city of Hartford, Connecticut. It weighs eight and a half tons, and throws thirteen hundred and fifty gallons of water a minute. The ordinary horse-draught fire-engine weighs about three tons, and throws five or six hundred gallons of water a minute.

hours a day. When it is left in the street outside, the doctor takes with him a little brass plug, or key, without which the vehicle cannot run away or be moved or stolen. And, moreover, it is swifter by half than the ordinary means of locomotion, so that in emergency cases it may mean the saving of a life. One New York physician recently put an electric cab to a most extraordinary use. His patient had a broken arm, and he wished to photograph the fracture with Röntgen rays, but there was no source of electricity available in the residence of the patient. So he made a connection with the battery in his cab, which stood at the door; the rays were promptly applied, and the injury was located.

While the electric vehicle has been winning plaudits for its work in the cities, where pavements are smooth and hard, the gasolene vehicle has been equally successful both in the city and in the country. For ordinary use the gasolene-propelled vehicle has many important advantages. It is much lighter than the electric vehicle; it requires no charging station, gasolene being obtainable at every cross-roads store; and it is moderately cheap. All of the famous long-distance races and rides in Europe have been made in gasolene vehicles. On the other hand, most of the gasolene vehicles are subject

to slight vibrations due to the motor, and it is almost impossible to do away entirely with the unpleasant odors of burnt gases. Gasolene vehicles are never self-starting, it being necessary to give the piston one turn by hand. In general, also, they are not as simple of management as the electric vehicle; there is more machinery to understand and to operate, and more care is necessary to keep it in order. But when once the details are mastered, the traveller can go almost anywhere on earth with his gasolene carriage: up hill and down, over the roughest roads, through mud and snow, a law unto himself. He can make almost any speed he chooses.

The power principle of the gasolene vehicle is very simple. It is a well-known fact that when gasolene is mixed with air in proper proportions and ignited, it explodes violently. By admitting this mixture at the end or head of the engine cylinder, and exploding it at the proper moment, the piston is driven violently forward, and then, by the action of the fly-wheel or an equivalent device, it is forced back again, and the motor is kept in motion. Most gasolene engines are of what is known as the four-cycle variety. During the first impulse of the piston the vapor is drawn into the end of the cylinder, during the second it is com-

A TYPICAL MOTOR TRUCK. MOTIVE POWER, COMPRESSED AIR.

pressed by the return of the piston, in the third it is exploded, and in the fourth the products of the combustion are driven out, and the end of the cylinder is ready for another charge. The explosion of the gas is produced in the most approved motors by means of an electric spark, there being no fire anywhere connected with the machine. Owing to the constant compression of the gases and the succeeding explosions, a gasolene motor becomes highly heated, and in order to maintain a normal temperature, it must be provided with a jacket of cold water, or a peculiar ribbed arrangement of iron for increasing the radiating surface. A vast number of ingenious devices are used for making all of these processes as simple as possible. One motor is so arranged that no igniter is necessary, the gas being compressed in the cylinder to such a degree that it explodes of its own heat, thereby doing away entirely with electricity or any other sparking device. In France most of the gasolene vehicles are still provided with what are known as "carburetters," or small chambers where the gas and air are mixed in the proper proportions and heated before they are driven into the cylinder. In this country carburetters have been largely done away with, the gas being mixed as it passes into the cylinder.

Every driver of a gasolene vehicle must know these general facts about the mechanism of his motor. He must know how to fill the gasolene and water tanks, how to replenish or regulate the battery which ignites the gas, and he must understand the ordinary processes of cleaning and oiling machinery. When he is ready to start, he must connect up the sparking device and turn the wheel controlling the piston until the explosions begin. After that, he must see that the valves which admit the air and the gas are carefully adjusted, so that the mixture is admitted to the cylinder in the proper proportions, and then he is ready to go ahead, steering and controlling his engine by means of levers, and operating the brake and gong with his feet. All gasolene vehicles are provided with numerous means of stopping, besides the ordinary use of the brake, so that there is practically no possible danger of a runaway. The Duryea vehicle, for instance, has no fewer than five different means of turning off the power of the motor, all within convenient reach. The secretary of the company that manufactures this vehicle told me that he had often stopped his carryall within 20 feet, when going at a speed of 20 miles an hour, without great inconvenience to the passengers. By a clever arrangement for changing gearings, the gasolene vehicle

can be made to ascend almost any hill, and it can be turned in half the space necessary for a horse vehicle.

It is astonishing how little fuel it takes to run a gasolene vehicle. One manufacturer showed me a phaeton weighing 700 pounds which he said would run 100 miles on five gallons of gasolene, a bare half-dollar's worth. A tricycle manufactured by the same company, weighing 150 pounds, will run 80 miles on three pints of gasolene.

Gasolene vehicles vary in cost over an even wider range than electrical vehicles. A tricycle can be obtained as low as $350, while an omnibus may cost into the thousands. A first-class road carriage, built with all the latest improvements and highly serviceable in every respect, can be obtained for $1,000. At this price, the manufacturers assert that gasolene power is much cheaper than horse power. One motor-vehicle expert has made some interesting comparisons, based on an average daily run of 25 miles for five years—more than the maximum endurance of a first-class horse. His estimates represent ordinary city conditions, and rate the cost of the gasolene used at one-half cent a mile:

GASOLENE MOTOR VEHICLE.

Original cost of vehicle	$1,000 00
Cost of operation, 1 cent per mile, 25 miles per day	456 50
New sets of tires during five years.	100 00
Repairs on motor and vehicle . .	150 00
Painting vehicle four times . . .	100 00
Storing and care of vehicles, $100.00 per year	500 00
	$2,306 50

HORSE AND VEHICLE.

Original cost of horse, harness, and vehicle	$500 00
Cost of keeping horse, $30.00 per month, five years	1,800 00
Repairs on vehicle, including rubber tires	150 00
Shoeing horse, $3.00 per month, five years	180 00
Repairs on harness, $10.00 per year.	50 00
Painting vehicle four times . . .	100 00
	$2,780 00

"At the end of five years," explained this expert, "the motor vehicle should be in reasonably good condition, while the value of the horse and carriage would be doubtful. There is always the possibility that at least one of the horses may die in five years, while the motor vehicle can always be repaired at a comparatively nominal cost. But even assuming that

A HORSELESS AMBULANCE ON THE BATTLEFIELD.

the relative value of each is the same at the end of five years, the cost of actual maintenance during that period would be $1,306.50 for the motor vehicle and $2,280 for the horse and vehicle, or $973.50 in favor of the motor vehicle. This comparison is really doing more than justice to the horse, because a motor vehicle can do the work of three horses without injury."

Steam has been successfully applied to the heavier grades of vehicles, notably trucks, fire-engines, and omnibuses; and two or three American manufacturers have gone still further, and have produced light and natty steam buggies and runabouts, and even steam tricycles. Steam vehicles are easily started and stopped, and fuel and water are always readily obtainable; but there is also the disadvantage of a slight cloud of steam escaping from the exhaust, accompanied by more or less noise. Moreover, in many States there are regulations (mostly unenforced in the case of motor vehicles) against the operation of steam-engines except by licensed engineers, and it is probable that steam automobiles will not be widely accepted for pleasure purposes until the inventors have succeeded in producing a strictly automatic engine.

Much has been said as to the use of compressed air for heavy trucks, and several im-

mense corporations have been organized to promote its use. The air is compressed at a central station, and admitted to heavy steel storage bottles, or tubes, connected with the truck and used much like steam. The main difficulty in the process has been the sudden cooling of the machinery when the air is released from pressure and begins to take up heat. Often the pipes and valves are frozen solid. To deal with this problem, a jacket of water heated by a gasolene flame is provided for "reheating" the air, a difficult and cumbersome process. Owing to the weight of the steel tubes, the compressed-air vehicles are enormously heavy, and, like electric vehicles, they must return to some charging station, after travelling 20 or 30 miles, for a new supply of power. And yet both inventors and financial promoters are sanguine of ultimate success with them.

A Chicago inventor has been building a truck in which he combines gasolene and electrical power. An eight-horse-power gasolene engine situated over the front axle drives an electrical generator, which in turn feeds a small storage battery, thus producing power as the vehicle moves, and rendering it entirely independent of a charging station. One man can handle the entire truck, and it is said that the cost of operation will not exceed 80 cents a day. The

main objection to this system, as with compressed air, is the enormous weight of the vehicle, which is upwards of 9,000 pounds. The truck has a carrying capacity of eight tons, making a total of 25,000 pounds. Such a vehicle presents problems which modern pavement builders have yet to solve.

But the time is certainly coming, and that soon, when all heavy loads must be drawn by automobiles. Recent English experiments, already mentioned, have established the feasibility of the auto-truck even in its present experimental stage, and the inventor needs no further encouragement to prosecute his work. It is hardly possible to conceive the appearance of a crowded wholesale street in the day of the automatic vehicle. In the first place, it will be almost as quiet as a country lane—all the crash of horses' hoofs and the rumble of steel tires will be gone. The vehicles will be fewer and heavier, although much shorter than the present truck and span, so that the streets will appear much less crowded. And with larger loads, more room, and less necessary attention, more business can be done, and at less expense.

A New York manufacturer produces an odd variation of the motor vehicle in what he calls a "mechanical horse." It is a one- or three-wheeled equipment provided with an electric

motor, and it can be attached to almost any kind of carriage or wagon body and used for propulsion like a veritable mechanical horse.

As to just what form the future motor vehicle will take there is the widest diversity of opinion. Business clashes with art. Horse carriages are built high so that the driver can see over the horse and avoid the dust. The first motor vehicles were merely "carriages-without-the-horse," and some of them looked clumsy and odd enough, "bobbed off in front," as one enthusiast told me. Strangely enough, however, manufacturers say that at present the public demands just such vehicles, the low, light, and comfortable models being too much of an innovation to sell.

"But you may depend upon it," one manufacturer told me, "the future motor vehicle will be within a step of the ground, with an artistically rounded front, neither a machine nor a carriage-without-the-horse, but a new and distinct type—the motor vehicle."

The utility of the automobile in any city is in direct proportion to the condition of its streets. It is hardly surprising that manufacturers are receiving the greatest number of inquiries from cities like Buffalo and Detroit, where the pavements are good, and from California and part of New England. The automobile has had such

A DAIMLER MOTOR CARRIAGE ON THE PONT AU CHANGE, PARIS.

It was a carriage of the same model as the one shown here that came in first in the race from Paris to Bordeaux, on June 11, 1895.

acceptance in France because the highways are all as smooth as park paths. Bicycling already has had a profound influence in spurring the road-makers, and the introduction of the motor vehicle will be still more effective. Colonel Waring estimated that two-thirds of all street dirt is traceable to the horse. At present it costs New York nearly $3,000,000 a year to clean its streets. With new pavements such as the new soft-tired vehicles and the absence of pounding hoofs would make possible, street cleaning would become a minor problem. And new asphalt pavement, the best in the world, could be put down at the rate of 40 miles a year for what New York now spends for half cleaning its streets.

As yet American law-makers have hardly touched on the subject of motor vehicles. In New York, if drivers keep out of Central Park, display a light, ring a gong, and do not speed faster than eight miles an hour, no one interferes with them. Similar regulations prevail in Boston, and in other American cities. In Brooklyn the parks are free. France and England, on the other hand, hedge in automobile drivers with all manner of rules and regulations, and require them to be officially licensed. In France, by recently promulgated articles, every type of vehicle employed must offer com-

plete conditions of security in its mechanism, its steering gear, and its brakes. The constructors of automobiles must have the specifications of each type of machine verified by the *Service des Mines.* After a certificate of such verification has been granted, the constructor is at liberty to manufacture an unlimited number of vehicles. Each vehicle must bear the name of the constructor, an indication of the type of machine, the number of the vehicle in that type, and the name and domicile of its owner. No one may drive an automobile who is not the holder of a certificate of capacity signed by the prefect of the department in which he resides.

The regulations are most explicit on the important question of speed. In narrow or crowded thoroughfares the speed must be reduced to walking pace. In no case may the speed exceed 18½ miles an hour in the open country, or 12½ miles an hour when passing houses. Relative to signals, the regulations say that "the approach of an automobile must, if necessary, be signaled by means of a trumpet." Each automobile must be provided with two lamps, one white, the other green. Racing is allowed, provided an authorization is obtained from the prefect and the mayors are warned. In racing, the speed of 18½ miles an hour may be exceeded in the open country, but when

passing houses, the maximum of 12½ miles must not be exceeded.

One curious difficulty in connection with the new vehicle is the difficulty of finding suitable English names to designate it and its driver. The French, with characteristic readiness in getting settled names for things, have, as already noted, formally adopted the word "automobile" for the vehicle and "chauffeur" (stoker) for the driver. But we of the English tongue are slower. At least a dozen names have been used to a greater or less extent, such as "motor carriage," "auto-carriage," and "horseless carriage." In England, "self-propeller" is popular and so is "auto-car," the latter being apparently the favored designation. "Motor vehicle" seems to be the more generally accepted name in this country. But whatever it is, or is yet to be called, the thing itself must now be rated an accepted and established appliance of every-day life.

PHOTOGRAPH OF A LADY'S HAND, SHOWING THE BONES, AND A RING ON THE THIRD FINGER, WITH FAINT OUTLINES OF THE FLESH.

From a photograph taken by Mr. P. Spies, director of the "Urania," Berlin.

CHAPTER V.

X-RAY PHOTOGRAPHY.

Dr. Röntgen's Great Discovery.

PERHAPS no inventor ever achieved world-wide distinction so quickly as Dr. William Konrad Röntgen. He discovered his famous X-Rays on November 8, 1895; in December he described them before the Würzburg Physico-Medical Society; in January the marvel of the new rays which penetrate and photograph through almost every known substance was known all over the world, as well to newspaper readers as to the learned societies. A few months later many prominent scientists, both in Europe and in America, were experimenting with Röntgen's rays, and within a year they had become a regular and exceedingly important factor in surgical operations. Moreover, no one disputed the originality of Dr. Röntgen's discovery; he had invented the first machine for photographing through solid substances, for taking pictures of the skeleton framework of the human body through the

flesh. No one ever before had done that, and the scientific world was quick with its appreciation and liberal with its honors.

And yet this discovery, which many scientists rank side by side with Lister's system of antiseptics in its importance as a life saver, was not the result of happy chance. It was not mere luck. At the time that Dr. Röntgen saw the X-Rays shimmering and glowing for the first time on a bit of sensitive paper he was past fifty years old, and during the greater part of his life he had been working quietly but industriously and thoughtfully with the great problems of physics and electricity. He laid the foundation of his career in a thorough education at Zurich, his birthplace, and at Utrecht. Seven years before the discovery he had become a professor at the Royal University in the quaint old Bavarian town of Würzburg. Here, in a bare little laboratory in an equally modest two-story house, with few of the modern appliances, he made his famous experiments, and from here he went out when the world heard of him to receive the praise and decorations of his emperor. And after that he returned to his work, just as if he wasn't famous.

Dr. Röntgen (pronounced Rentgen) is a tall, slender, somewhat loosely built man, with a

DR. WILLIAM KONRAD RÖNTGEN, DISCOVERER OF THE X-RAYS.

From a photograph by Hanfstaenge, Frankfort-on-the-Main.

bushy beard and long hair rising straight up from a high white forehead. When he is excited or much in earnest he thrusts his fingers through this mass of hair until it bristles all over his head. He has an amiable face, with kindly although penetrating eyes. His voice is full and deep, and he speaks with the rapidity of great enthusiasm. Indeed, his whole bearing tells of boundless energy and unremitting vigor. One visitor compared him on first sight to an amiable gust of wind.

Previous to the discovery which made him famous, Dr. Röntgen had actually been producing and working with X-Rays for some time without knowing it. Indeed, other scientists had been doing much the same thing—experimenting all unconsciously on the very verge of the greatest discovery of years, but it remained for Dr. Röntgen, with his keener scientific insight, to see the unseen.

The famous electrician Hertz, whose discoveries have made possible more than one great invention, had tried sending a high-pressure electric current through a vacuum tube, a so-called Crookes tube. A vacuum tube is a vessel of very thin glass, having a platinum wire fixed in each end. This vessel is as nearly empty of everything as human ingenuity can make it; even the air is pumped out until only one

one-millionth of an atmosphere remains. Hertz connected one of these tubes to the poles of his battery by means of the platinum wires. When the discharge began he observed that the anode

COINS PHOTOGRAPHED INSIDE A PURSE.

From a photograph by A. A. C. Swinton, Victoria Street, London.

—that is, the end of the tube connected with the positive pole of the battery—gave off certain peculiar and faint bands of light. But these were quite insignificant compared with the brilliant and beautiful glow at the other or

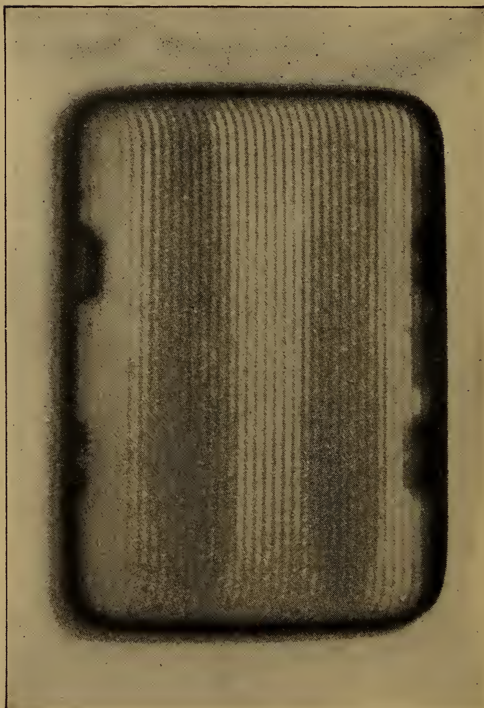
SKELETON OF A FROG, PHOTOGRAPHED THROUGH THE FLESH. THE SHADINGS INDICATE, IN ADDITION TO THE BONES, ALSO THE LUNGS AND THE CEREBRAL LOBES.

From a photograph by Professors Imbert and Bertin-Sans; reproduced by the courtesy of the "Presse Medicale," Paris.

negative end of the tube, which is called the cathode. This glow resembled somewhat the fierce burning of an alcohol lamp, only it was softer, more evanescent, and more striking in its coloring. It produced brilliant phosphorescence in glass and many other substances, and Professor Lenard, Hertz's assistant, observed, in 1894, that the rays — "cathode rays," as they were called—would penetrate thin films of wood, aluminum, and other substances. But this was as far as any of the experimenters who preceded Röntgen succeeded in going.

Strangely enough, both Hertz and Lenard produced X-Rays in abundance without knowing it. These were, indeed, present in the glow from the cathode, only they were entirely invisible to the human eye. They are different from the rays described by Lenard, in that they are not deflected—that is, turned aside—by a magnet, and they are incomparably more powerful in range and in penetrating power. It will be seen, therefore, that while Dr. Röntgen was not working in a wholly new field, his discovery is none the less entirely original.

The discovery itself was made in a peculiarly interesting way. Dr. Röntgen had been experimenting steadily for several weeks with his Crookes tubes. One day he had covered the



PICTURE OF AN ALUMINUM CIGAR-CASE, SHOWING CIGARS WITHIN.

From a photograph by A. A. C. Swinton, Victoria Street, London. Exposure, ten minutes.

tube with a light-excluding black shield. Then he had darkened his laboratory so that not a ray of light could anywhere enter. To the eye everything was absolutely black. When the electric current was turned on, the

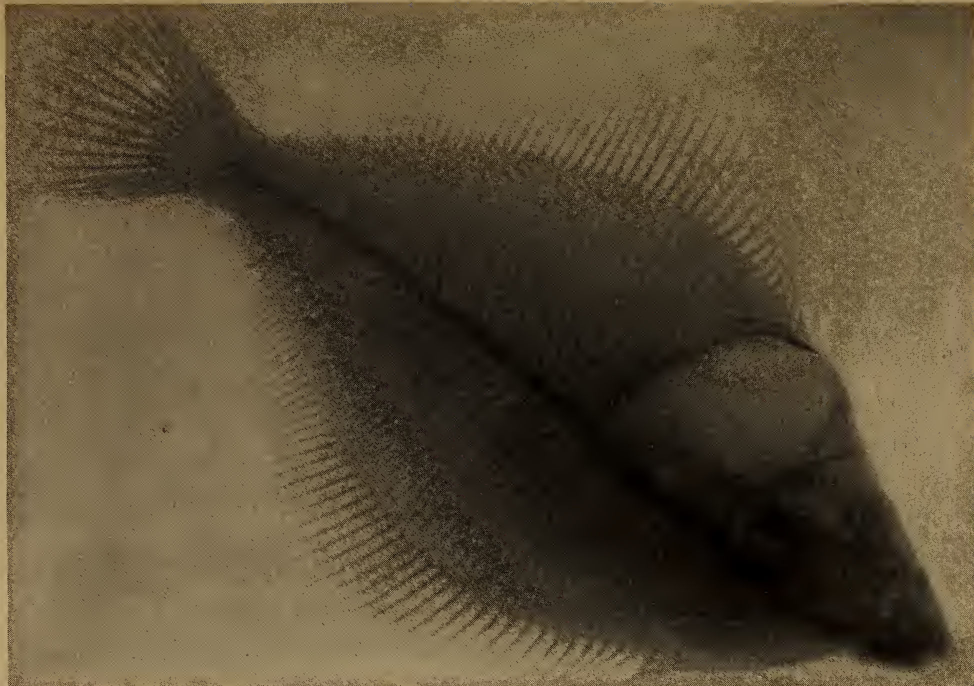
A HUMAN FOOT PHOTOGRAPHED THROUGH THE SOLE OF A SHOE. THE SHADING SHOWS THE PEGS OF THE SHOE AS WELL AS TRACES OF THE FOOT.

From a photograph by Dr. W. L. Robb of Trinity College.

hooded tube did not show even a glint of light; but something on a shelf below began to glow, very strangely. It was a piece of sensitive paper—barium platino-cyanide paper. Dr. Röntgen knew that no light could come from the tube, because the shield that covered it was wholly impervious to light—even the strongest electric light. Where, then, did it come from? Dr. Röntgen began at once an eager investigation, moving the sensitive paper from side to side and covering the tube with a still denser screen. And finally he came to the conclusion that certain unknown rays, whether of light or not, he did not know, were actually coming through the screen, and giving the sensitive paper a distinct luminescence. It was contrary to all reason, to everything that the text-books taught, and yet Dr. Röntgen was forced to believe it. And having discovered the existence of the new rays, he began at once to experiment with them. He found that they readily penetrated paper, wood, and cloth, and that the thickness of these mediums made little difference. That is, they would penetrate a thick book almost as easily as they would a single sheet of paper. Then he tried photographing, and found to his astonishment that the rays affected the sensitive film of the photographic plate, leaving the shadows of the objects ex-

posed plainly outlined. For instance, he placed bits of platinum, aluminum, and brass inside of a wooden box, and found that not only did he get skiagraphs (shadowgraphs) of them through the wood, but all the nails that held the box together and the brass hinges were likewise reproduced. Then he photographed a spool of wire, the wooden ends of the spool leaving a very faint shadow, and the wire a dark one. When he tried glass, which is one of the most transparent of substances so far as ordinary light is concerned, he found that the new rays passed through it only with difficulty, and that aluminum was much more transparent to them than glass. In other words, if we lived in an X-Ray world we might use aluminum for windows to let in the X-Ray "light," and glass for shutters to keep it out.

After many experiments of this kind, it suddenly occurred to Dr. Röntgen that if the new rays penetrated all manner of substances, they would also penetrate the human body; that, in fact, they were probably going straight through his hands and his head as he worked with them. So he placed his hand, palm down, on a photographic plate, still in its black holder, arranged the Crookes tube above it, turned on the current, and in a short time he had a photograph, dim, it is true, but perfect, of the bony frame-



SKELETON OF A FISH PHOTOGRAPHED THROUGH THE FLESH.

From a photograph by A. A. C. Swinton. Victoria Street, London. Exposure, four minutes.

work of his hand—the first of the kind ever taken, and a marvel up to that time absolutely inconceivable.

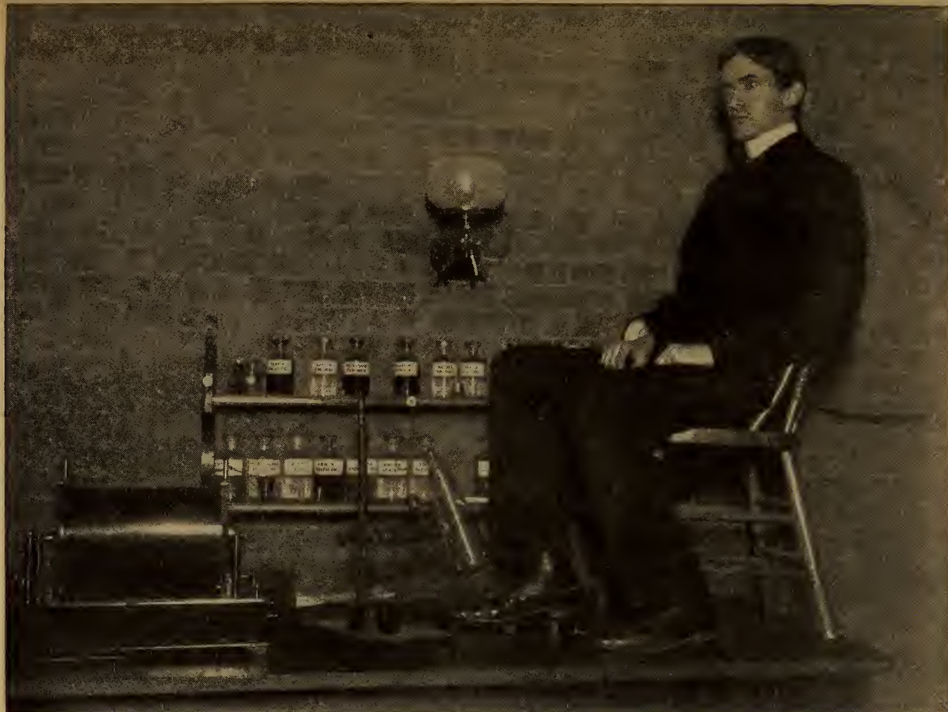
A little later he built a closet of tin just big enough to accommodate one man comfortably, and fitted it up with an aluminum window. Outside of the window he placed his new apparatus. Only the new rays would, of course, shine through the aluminum, and he could study them at his leisure. But after long and careful experimenting he could not decide what the new rays really were, and although many theories have been advanced by prominent scientists, a really satisfactory explanation is still wanting. It is pretty generally believed, however, that Röntgen's rays are only a "mode of motion" through the ether—that is, they are produced by a certain peculiar kind of vibrations in the ether. Dr. Röntgen himself gave them the name "X-Rays"—the unknown rays.

But if the exact nature of the rays was a mystery, their uses and importance became familiar almost immediately. The apparatus was so simple that it could be fitted up in almost any laboratory. It consisted merely of a battery or dynamo current; a coil, usually a Rhumkorff coil, for intensifying the current, and a Crookes tube, which might have any one

of twenty-odd shapes. As a result of this simplicity thousands of surgeons and scientists were able to prepare experimental apparatus, and some of the results in this country were excellent, especially in photographing the human skeleton.

Even Edison, the greatest of American inventors, took up the work with great enthusiasm, and he shortly invented a curious but simple device by means of which one may actually see the bones of the hand or foot through the flesh. He called it the fluoroscope. It is merely a wooden box, larger at one end than at the other, the smaller end being so constructed and padded with cloth that it will fit exactly over the eyes without admitting any light. The other end of the box is covered with a sheet of thin cardboard coated with a chemical compound which becomes fluorescent —that is, shines or glows—when placed in range of the X-Rays. By holding this box between one's eyes and a Crookes tube, and placing one hand on the sensitive cardboard, the X-Rays will readily pierce the flesh, and the dark shadow of the skeleton of the hand may be seen. In this way a doctor can tell quickly the location of a bullet or a needle in the hand or foot, for he is able to look through the flesh as if it were glass.

THOMAS A. EDISON EXPERIMENTING WITH THE RÖNTGEN RAYS.



PHOTOGRAPHING A FOOT IN ITS SHOE BY THE RÖNTGEN PROCESS.—A PICTURE OF THE ACTUAL OPERATION WHICH PRODUCED THE PHOTOGRAPH SHOWN ON PAGE 183.

From a photograph by Dr. W. L. Robb of Trinity College. The subject's foot rests on the photographic plate.

The Röntgen rays have been put to many marvellous uses, most of them connected with bone photography in surgery cases. And, strangely enough, when a physician is ready to photograph a broken arm, for instance, to see if it is properly set, he never thinks of removing the splints or the bandages; he simply photographs through them. And that is the reason why such a photograph often shows pins and buckles. Frequently, in cases where the patient is very weak, the photograph is taken through the bed-clothes as well as through the bandages—it doesn't make the slightest difference to these wonderful rays. It takes from two minutes to more than a hour to get a good skiagraph, but the operation is no more painful, if we count out the necessity of keeping still, than having a snap-shot taken.

One of the earliest skiagraphs, showing the medical importance of the X-Rays, was taken in England. A boy of nineteen had injured his little finger playing ball, so that it was bent at the last joint, and he could neither extend it nor bend it further down. Any attempt to do so caused him sharp pain. Before the skiagraph was taken the doctors declared that the finger must be amputated. A skiagraph showed, however, that there was only a little bridge of bone uniting the last two joints,

thereby preventing the proper flexing of the finger. As soon as this was known an anæsthetic was administered, and by the use of a little force this bridge of bone was snapped, and the finger saved. That was the first finger to the credit of Dr. Röntgen's discovery.

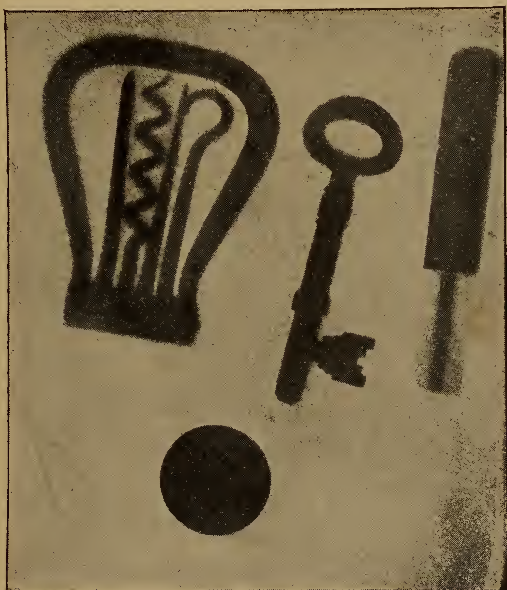
Since then the X-Rays have been used constantly for finding bullets embedded in the flesh—X-Ray machines are now taken to war with every civilized army—for finding needles that have been driven into the foot, for examining deformities of the bones, and, more recently, for photographing foreign bodies in the larynx and windpipe, and even in the stomach. Think of the sufferings caused by probing for bullets, shot, and needles in the flesh, all saved by an easily taken skiagraph!

An English woman came to a doctor saying that she was suffering tortures from her shoes, so that she found it difficult to walk, and she even wanted some of her toes amputated. A skiagraph showed exactly what the trouble was. She had been wearing shoes much too small for her, and the bones had become wofully twisted and bent. One sight of the photograph convinced her that she must wear broad-soled shoes. In a somewhat similar case in Austria, the doctors found that the great toe of the patient was twice as large as

BONES OF A HUMAN FOOT PHOTOGRAPHED THROUGH THE FLESH.

From a photograph by A. A. C. Swinton, Victoria Street, London. Exposure, fifty-five seconds.

it should be. They found by feeling that there were two bones instead of one, but they could not tell which was the normal bone and



CORKSCREW, KEY, PENCIL WITH METALLIC PROTECTOR, AND PIECE OF COIN, AS PHOTOGRAPHED WHILE INSIDE A CALICO POCKET.

From a photograph by A. A. C. Swinton, Victoria Street, London. Four minutes' exposure through a sheet of aluminum.

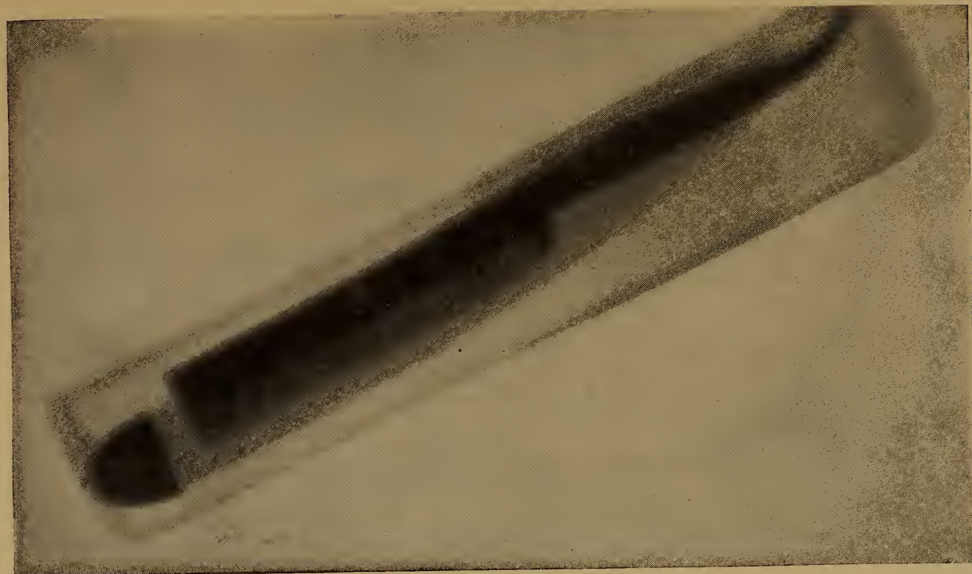
which the one to be removed. A skiagraph showed the whole condition instantly.

One of the strangest uses to which X-Rays ever have been put was at the instance of a

Philadelphia woman. She had been travelling in Egypt, and had brought home what she believed to be the hand of a mummy. But some of her friends told her how Egyptian curiosities are likely to be manufactured and sold to unsuspecting travellers as genuine relics. One friend, himself a great traveller, assured her that she had bought a mere mass of pitch, plaster of Paris, and refuse mummy-cloth, not a hand. For a long time there was no way of deciding the question, until at last the owner of the relic had an X-Ray photograph taken. And lo and behold! there in the picture was the complete skeleton of the hand of some ancient Egyptian; the relic was genuine, after all.

Another curious and important use of X-Rays is in determining genuine from imitation diamonds. A European scientist has made many tests in this field, and he finds that while the X-Rays will penetrate the genuine diamond and leave almost no shadow in the photograph, the false ones are nearly opaque to the rays, and appear very dark in the photograph. This unusual new test may some time supersede all others.

A great many experiments have been made looking to the use of X-Rays in curing diseases. Several prominent physicians assert



RAZOR BLADE PHOTOGRAPHED THROUGH A LEATHER CASE AND THE RAZOR HANDLE.

From a photograph taken by Dr. W. L. Robb of Trinity College. The shading in the picture indicates, what was the actual fact, that the blade, which was hollow ground, was thinner in the middle than near the edge.

that the new rays kill all germs—consumption, typhoid fever, diphtheria, and so on—and that by applying them properly to the diseased portion of the body a cure may be effected. This has not been proved as yet, but we may hope that the belief is well founded. In any event, we may expect to hear of many wonderful developments in coming years from Dr. Röntgen's discovery.

THE KITE BUOY IN SERVICE.

CHAPTER VI.

TAILLESS KITES.

What They Will Do and How to Make Them.

One of the most famous of kite-flying explorers compares mankind to crabs living at the bottom of the sea—only ours is a sea of atmosphere. Here we lie close to the earth, knowing comparatively little of the vast heights of air above us, of the immeasurable waves which sweep through it back and forth, and of the strange phenomena of heat and cold, rainfall, snow, sleet, frost, dew, cloud formations, tornadoes, waterspouts. The Eiffel Tower, the tallest structure ever built by man, reaches only 1,000 feet high; the Washington Monument is a mere 555 feet, while the top of the earth's atmosphere lies more than forty-five miles straight above us. Until the recent experiments in kite-flying were begun men had never been able to make regular records of the conditions of the atmosphere at any particular spot more than a few hundred feet above the earth. It is true that aëronauts had reached

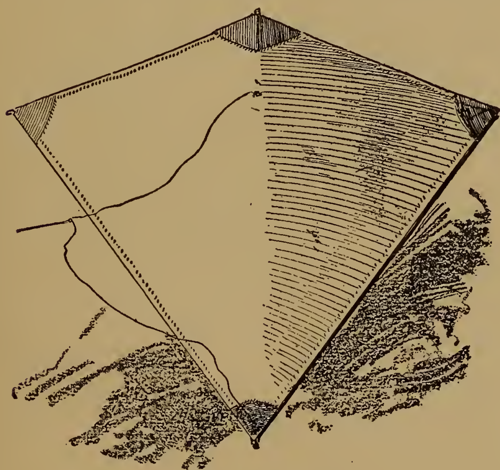
great heights in their balloons, but their passage through the air was so swift and so uncertain that they added little to scientific knowledge. Strangely enough, while regular investigations were being made a mile or more beneath the earth's surface, in the deepest mines, science was unable even by its cleverest devices to go 1,500 feet above the earth and remain there long enough to make any observations of great value.

But with the coming of the modern kite all this is changed. And it is wonderful enough to watch the kite scientists forging higher and higher every year into the atmosphere, just as explorers in the Arctic are pushing northward to the pole.

On November 7, 1893, Mr. W. A. Eddy sent a kite 5,595 feet in the air—a little more than a mile. This was regarded at the time as a most astonishing performance, but three years later, on October 8, 1896, the same experimenter made a record of 9,400 feet. In the meantime many other investigators were at work in England, Australia, and in many parts of the United States, so that the limit kept creeping up and up, a thousand feet every year, until, on February 28, 1899, the kite flyers of the Blue Hill Observatory near Boston broke all previous records by sending a team of kites

12,507 feet, or nearly two and one-half miles above the surface of the earth. And there is no doubt that they will go still higher and find out still more important things about our atmosphere.

It seems odd to speak of the kite as a new

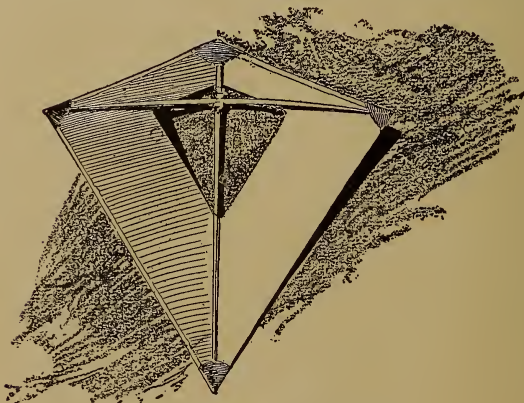


THE EDDY TAILLESS KITE.

Front view, showing how the line is attached.

invention, for kites were used in China and Japan long before the beginning of written history. The Chinese have long built kites in the form of huge dragons, and have made them play curious music as they floated high in the air—keeping away the evil spirits, as all Chinamen firmly believe; and kite-fighting is

a familiar sport in Japan. Every schoolboy knows how Franklin drew the lightning from the clouds by means of a kite string, and more than fifty years ago a Scotch experimenter, Dr. Alexander Wilson, had sent up thermome-

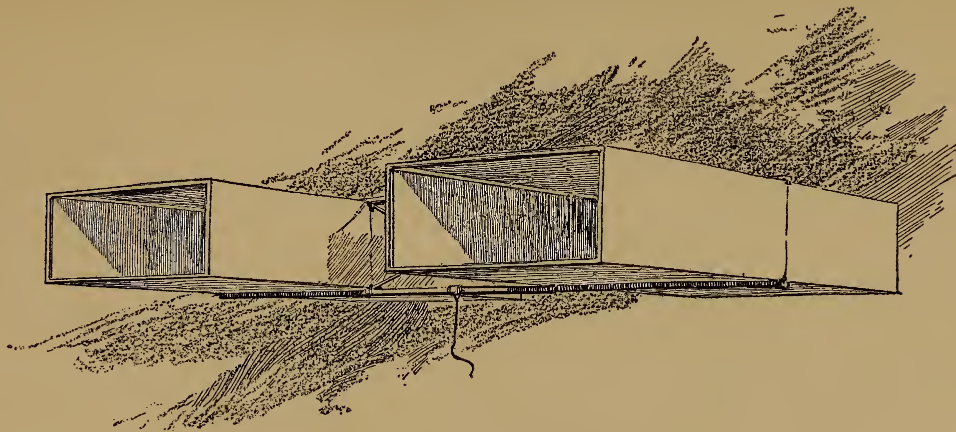


THE EDDY TAILLESS KITE.

A storm-flyer.—The diamond-shaped figure in the centre is an opening made to lessen the wind pressure.

ters attached to kites in order to determine temperatures at high altitudes.

But the tailless kite, the kite that will lift a man high in the air and that will penetrate miles into space, is a purely modern invention. And curious enough a flock of these new kites appears—those of the Eddy model resembling giant bats, and those of the Hargrave model giving the impression of a number of big paste-



THE HARGRAVE BOX KITE.

It was by kites of this variety, flown in tandem, that the inventor, Hargrave, was lifted sixteen feet from the ground on November 12, 1894.

board boxes with the bottoms knocked out. Some of them are so large, twice the height of a man and more, that when they first appeared in various parts of the country, people took them for mysterious air ships, and the newspapers were filled with the accounts of various people who had seen these strange ships in the skies.

There are two important varieties of the new kites. The first is that invented by W. A. Eddy, of Bayonne, New Jersey. It is modelled somewhat after the kite used so long ago by the Malays, and it looks a little like the old-fashioned boy's kite, only it is broader and it has no tail. The other new kite was invented by Lawrence Hargrave, of Australia. It is merely a very light box frame, with a band of cloth around each end, and it is so very different from every preconceived notion of a kite that one can hardly believe it will fly until he actually sees it in the air. It is an entirely original invention, and there are many who think that it is the mechanism which will eventually develop into a successful flying machine. Many other forms of kites are used by experimenters, but they are all variations or combinations of these two.

Mr. Eddy began flying kites to amuse his little daughter, but it wasn't long before he

became deeply interested in them from a scientific point of view. Indeed, so remarkable were some of his early experiments that they

NEW YORK, EAST RIVER, BROOKLYN, AND NEW YORK BAY, FROM A KITE.

From a kite photograph taken by Mr. W. A. Eddy.

won for him the name "Kite King." In 1895 he had built kites strong enough to carry upward small objects of considerable weight, and so he sent aloft a photograph camera, and

by a peculiarly ingenious device he sprung the shutter and took a beautiful picture, a bird's-eye view of the earth below, the first of the

CITY HALL PARK AND BROADWAY FROM A KITE.

From a photograph taken from a kite by Mr. W. A. Eddy. City Hall Park, New York City, appears in the foreground, with Broadway back of it.

kind ever taken. After that he flew his kites over New York, and made pictures of City Hall Square and the tops of some of the great buildings as they look from above. Several times he was able to fly his kite far out, many blocks

away from the top of the building on which he stood, and he argued from this that the kite could be made a valuable adjunct in war. For

William Street.

Frankfort Street.

PHOTOGRAPHIC VIEW FROM A KITE.

This view, from a photograph taken from a kite by Mr. W. A. Eddy, shows a bit of New York City at the crossing of Frankfort and William Streets.

instance, if two armies lay behind breastworks not far apart, one of them might, when the wind was in the right direction, fly a kite over the enemy's works, and take a photograph

showing the exact strength of the fortress in guns and in men. The enemy might fire on the kite, but the target would be small and hard to hit, and a good many bullets might puncture its cloth sides without bringing it down. A kite flown from the war-ships before Santiago might have shown the strength of the enemy in the shore batteries. More than this, kites may some day be used as terrible engines of destruction. Think what havoc could be wrought in an enemy's camp if a tandem of kites should be sent over it, perhaps in darkness, with a load of dynamite, to be dropped at the proper moment. Mr. Eddy has found from his experiments that it would be perfectly possible to bombard Staten Island with dynamite dropped from kites sent up on the New Jersey shore.

By far the most exciting and dangerous of kite experiments has been the attempt to make kite ascensions. Think of it! A man carried aloft on a kite string, supported by a few cloth-covered boxes. This feat has been performed by Lawrence Hargrave; Captain B. Baden-Powell, of the Scots Guards; by Lieutenant Hugh D. Wise, of the United States Army, and still later by Charles H. Lamson, of Portland, Maine, who was actually carried more than fifty feet into the air on a single kite.

ONE OF CAPTAIN BADEN-POWELL'S TWELVE-FOOT KITES.

Captain Baden-Powell had some most thrilling experiences. During his experiments, he had occasion to build what was probably the largest kite ever flown. In May, 1894, he made a huge contrivance of bamboo and canvas, thirty-six feet high, with an area of 500

THE START.

square feet—as large as the side of a house. The very first time he sent it up it collapsed with a mighty crash, and came tumbling to the ground.

"I smashed dollars and dollars worth of bamboo," he says. "Again and again when I

thought I had a really good piece of apparatus, some little detail would go wrong; the kite would rise up in the wind, turn sideways, and come plump down against the ground, smashing every bone in its body."

But these are the trials that a kite enthusiast

A LULL IN THE WIND. CAPTAIN BADEN-POWELL IN THE BASKET.

must endure. Captain Baden-Powell, however, was not to be beaten. He kept on trying, until, on June 27, 1894, the great kite went up in fine style. The question was: Would it lift a man? The wind freshened up sharply, there was a creak in the basket, and up it went with

one of Captain Baden-Powell's friends aboard —the first time, perhaps, in the history of the world, that a man had been lifted from the ground by a single kite. After that it lifted the Captain himself. Following this success,

"WILL IT LIFT A MAN?"

Captain Baden-Powell made numerous ascents with tandem kites, even giving a public exhibition before the wise men of the British Association.

In the course of his experiments, Captain Baden-Powell at one time nearly lost his life.

In his own words: "I very nearly experienced a new sensation." It seems that one of his sets of kites was flying low, and the long, light line that held it lay entangled on the ground. The Captain stooped over to straighten it out, when

"UP IT WENT."

in some inexplicable manner his foot became entangled. Before he knew it, the kites sprung upward with a freshening breeze, threw him down, and began dragging him swiftly across the field by his foot. Just as he was being lifted entirely from the ground, a bystander

CAPTAIN BADEN-POWELL IN THE BASKET LEAVING THE GROUND, BUT STILL HELD BY BYSTANDERS.

seized him, dragged him down, and cut the rope. Lieutenant H. D. Wise had a similar and equally dangerous accident while he was experimenting with man-lifting kites on Governor's Island in New York Harbor. One day his kite line became entangled in the reel, and in order to get it loose, he tied himself to the line above the reel, thinking he could hold the kites while he made the necessary repairs, the wind then being somewhat slack. He drew his knife and cut the line close to the windlass. It parted with an unexpected snap, jerking the knife out of his hand, and before he was aware, the great kites were dragging him recklessly across the lawn in the direction of the open sea. After a moment of mad scrambling, the Lieutenant succeeded in regaining his feet. He was now only a few rods from the sea-wall, while the kites were far out above the blue waters of the harbor. There was a single chance for safety; a lamp-post stood well off to one side. Lieutenant Wise saw it and made a wild dash sideways for it, clasped it in both arms, and clung to it in a fond embrace until help arrived. It required three stout soldiers to lead the runaways back to their tether.

Lieutenant Wise made numerous ascents to a height of forty feet; there would have been no difficulty in going higher had it been deemed

IN THE BASKET, FORTY FEET FROM THE GROUND.

safe. For his first ascent he used four kites, with an area of 312.6 square feet. The four

kites weighed fifty-nine pounds, the ropes weighed twenty pounds, and the chair and man weighed 150 pounds, a total of 229 pounds lifted. Lieutenant Wise believes that while the kite cannot be expected to supersede the balloon, it will be very valuable in war time for signalling, both with lights and with flags. Kites are cheap, light, and can be rolled up in a small space, and he suggests that ten of them would be a valuable equipment for a war-ship. This number would easily lift a man to such a height that he could survey the sea with a telescope for many miles in all directions.

Captain Baden-Powell speaks even more favorably of the future of the kite.

"As compared with a balloon equipment," he says, "this apparatus presents important advantages. My entire 'kiteage,' with ropes and all, weighs only a little over a hundred pounds, and can be carried by two men. When the order is given to ascend, I can unpack, set up, and send up the kites in about five minutes. I now require no manual labor to haul down, as the kites can be lowered by a gentle pull on the 'regulating line,' which determines the angle they present to the wind. If the apparatus catches in a tree and gets torn, it makes but little difference, and the injury is easily remedied. If it were a balloon to which

the mishap befell, the gas would be lost, three wagon-loads more would be required to refill it, and it would need very careful patching before it could be used again. The same advantage would be held by the kite if a hostile bullet had penetrated either apparatus. And then, finally, the kite would involve, originally, probably not the twentieth part of the cost of the balloon, perhaps not a hundredth part."

Another interesting application of the modern kite has been suggested by Professor J. Woodbridge Davis, of New York. For some years he has been experimenting with a dirigible, or steerable, buoy, which may be drawn across wide stretches of water at the end of a kite line. It is merely a long wooden tube, about three inches in diameter, and shaped very much like a torpedo, with a cone of tin dragging behind as a rudder. A message placed in this buoy can be sent from a wrecked ship to shore, or in some cases from the shore to the wreck, or a line attached to the buoy may be dragged through the water. Professor Davis has experimented repeatedly with this buoy and with one of a larger pattern, and he has succeeded in making the kites drag them in various directions even in strong gales.

By far the most important and significant

EMPTY BASKET ABOUT SEVENTY-FIVE FEET FROM THE GROUND.

work now being done with kites is the systematic exploration of the upper heights of the air. Much valuable scientific knowledge has already been gathered by the Blue Hill Observatory of Boston. And more recently, the Weather Bureau of the United States government has taken up the work on a very extensive scale, and is making regular observations, at the uniform height of a mile, at sixteen stations, located in different parts of the country.

The Weather Bureau has reduced kite-flying to a thoroughly scientific system, so that the powerful kites which it flies can be controlled with the greatest ease. When flying at an elevation of from 5,000 to 7,000 feet, one of the Weather Bureau kites, supporting the instruments which record the conditions of the air, will pull from sixty to eighty pounds, if not more, and from 8,000 to 10,000 feet of wire will be out. To wind in all this wire under such conditions is really a very laborious operation, and generally requires two men at pretty hard work for three-quarters of an hour or more. As a substitute for the ordinary kite string or cord, the Weather Bureau, as well as all other advanced flyers, uses fine piano wire, which is smaller and much stronger in proportion than any hempen or flaxen cord. The winding of two or three miles of this fine

wire on a drum or reel introduces a serious problem. So tight does the wire become that 2,000 turns of it will produce the almost inconceivable pressure of 500 tons. A wooden reel is crushed like so much pasteboard, and it has been found necessary to use the strongest possible drums of iron, reinforced with heavy flanges. Indeed, at the Arlington kite station, opposite Washington, the kite wire is reeled in by steam power—a lively little oil engine easily doing the work of several men. What would the boys of ten years ago have said if they had been shown a complete machine for flying kites by steam?

The improved Hargrave kite is used almost exclusively for the regular government observations, although experiments with new forms are constantly being made, many having curiously shaped cells, some with divergent ends, wings, tails, and other queer appendages. The average size is seven feet long, six feet wide, and three feet high. The steel wire used is 30-1,000 of an inch in diameter, and weighs fifteen pounds to the mile, and is capable of sustaining a tension of 300 pounds. This is none too heavy, because the pulling power of these kites in strong winds frequently reaches 120 pounds or more. To have a kite fly away with the expensive instruments which it carries

PHOTOGRAPHING FROM A KITE LINE.

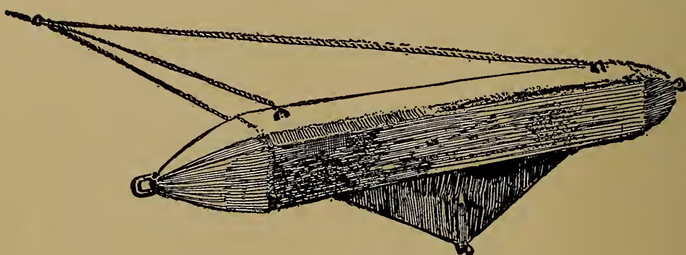
In this picture the square box suspended from the upper line is the camera. The ball hanging from the camera is the burnished signal, which, by its fall, informs the operator on the ground when the shutter of the camera has opened. The shutter and the ball are controlled from the ground by the lower line.

would mean a considerable loss, and the operators do not run the risk of sending the kites up in very heavy winds. The reel carries 20,709 feet, or nearly four miles of wire.

But perhaps the most wonderful of all kite improvements is the little machine called a meteorograph, which makes the records. The whole thing weighs only a little more than two pounds, so that one of the big kites can carry it easily, but it tells an extended story about the temperature, the moisture, and the barometric pressure of the air and the velocity of the wind, making a complete automatic record of all of these things in ink on a sheet of paper wound on a cylinder.

These records are made daily at each of the sixteen stations provided the weather is favorable, and the sheets are forwarded to the Weather Bureau, where they are carefully compared and tabulated and then filed away for reference. One of the most interesting and practical developments of these observations is the forecasting of cold and warm waves. Such changes in the weather are found to be apparent at a great height long before they reach the earth, and kite records have shown the approach of a change fully twenty-four hours in advance of its first indications at the surface.

Another curious fact which the kite scientists have learned is that at the height of a mile there are virtually no regular daily changes of temperature. In other words, the nights are as warm as the days. On the other hand, the days at this height are very damp, while night air is as dry as that of the driest desert—just the reverse of what it is on the earth. And



DIRIGIBLE KITE-DRAWN BUOY.

This is the buoy invented by Prof. J. Woodbridge Davis for conveying messages, food, or life-lines between disabled vessels and the shore. The buoy is drawn over the water by the kite line, like the one shown above, the setting of the keel and the three guy ropes giving it whatever direction is desired.

when a wind blows at these great altitudes, it blows like a tornado. It has been found that wind velocities at the height of a mile are four times as great as they are nearer the earth, and winds blowing 100 miles an hour are not uncommon.

Kites have been flown in rain-storms, in snow-storms, and in every other conceivable condition of weather. Indeed, the men who

make this their business have found that kites can be flown much more successfully at night than in the daytime, owing to the greater steadiness of the wind.

The scientific kite-flyer finds much to tempt him into the field of electricity. Mr. Eddy has succeeded many times in repeating Benjamin Franklin's experiment of drawing sparks from the clouds. Indeed, he has beaten Franklin, for he has frequently brought sparks from a clear sky, so that he believes that electricity is always present in large quantities in the air. An experimenter in the Blue Hill Observatory has sent up a kite coated with tin-foil for collecting electricity, but Mr. Eddy uses a special copper collector. Mr. Marconi, the famous in-

KITE-DRAWN BUOY.

Invented by Prof. J. Woodbridge Davis. This buoy lacks the steering appliances of the one shown on page 236, and travels simply in a line with the kite that draws it.

ventor of wireless telegraphy, who has actually used kites for supporting one of his sending wires, has suggested the possibility of getting enough electricity from the atmosphere with kite collectors to send messages, although he never has had time to develop the idea. It is

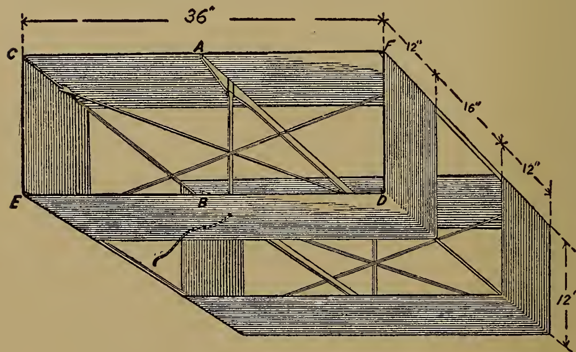


FIG. 1.—VIEW OF A MODERN BOX KITE.

certainly a rich field for the ambitious inventor.

It is comparatively easy to construct one of the new box kites, and the pleasure which comes from flying it will well repay the effort, for it will mount more easily and fly higher than any of the old-fashioned kites. Any moderately ingenious boy can make a box kite from the following description given by Mr. C. F. Marvin of the United States Weather Bureau, but he must be careful to follow di-

rections accurately, and not to slight a single detail of the work.

Mr. Marvin advises the use of the very best straight-grained spruce for the sticks, and either lonsdale cambric or calico for the covering. Some small tacks, and coarse, waxed linen thread, are also required. The sticks should be cut in the following dimensions:

Four lengthwise corner spines, one-fourth of an inch thick, five-eighths of an inch wide, and forty inches long.

Two central lengthwise spines, three-eighths of an inch square by forty inches long.

Two short vertical struts, one-fourth of an inch thick, one inch wide, and eleven and three-eighths inches long.

Four diagonal struts, one-fourth of an inch thick, five-eighths of an inch wide, and thirty-seven and three-fourths inches long.

The real backbone of the kite consists of a central truss, which is made up as shown in Fig. 2 (*AB* in Fig. 1).

The long sticks are three-eighths of an inch square. At five and one-half inches from each end a slight notch is formed on one side to receive the uprights. A notch is shown at *n*, and its depth should not exceed one-sixteenth of an inch. The uprights must be cut perfectly square and true on the ends, and are then cut

to the form shown at B. These are seated squarely in the notches of the long spines, and firmly lashed in place with coarse, waxed linen thread, as shown enlarged in Fig. 5. Waxed shoemakers' or harness-makers' twine is the best material for this purpose, but any coarse thread or fine string, thoroughly waxed, will suffice.

Fig. 3 shows the form to which the corner

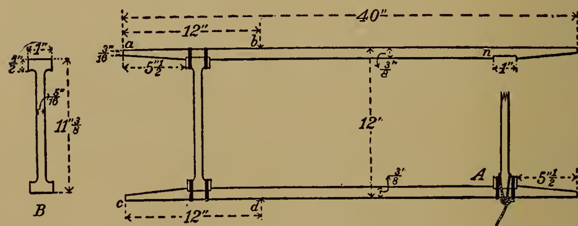


FIG. 2.—CENTRAL TRUSS.

longitudinal spines should be dressed, the long, straight edge being slightly rounded, as shown in the end view. Notice that the notches at the opposite ends are not at the same distance from the ends.

The covering of the kite is made of two long strips of cloth. Both edges of the strips should be hemmed, even if one edge has a selvage, and when so hemmed, the width should be just twelve inches. The total length of the strip, when stretched about as it will be on the

kite, should be ninety-six and one-half inches, the half inch being allowed for the lap of the goods in sewing the two ends together. It may be remarked here that it is generaly better to carefully *tear* the cloth to the proper length and width, rather than try to cut it, as more accurate results will be gained by the first method. The opposite ends of each cloth strip should be carefully and evenly lapped the

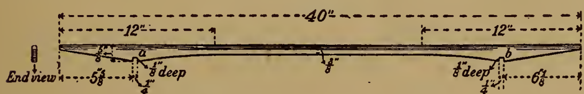


FIG. 3.—LONGITUDINAL CORNER SPINE.

one-half inch, and strongly sewed together with a double seam, thus forming two endless bands.

The next step is to mark the cloth bands at the places that are to be fastened to the frame. Stretch each cloth band out smooth and straight over two thin sticks run through inside the band. It is well to make the seam in the band come over or near the edge of one of the sticks. When the band is smooth and evenly stretched, draw a pencil line across the band exactly in the middle, where it turns around the edge of each stick. Let the line near the seam be marked *A*, and the opposite line *B*. Now shift the cloth around the sticks so that the lines *A* and *B* approach each other, but do not

pass. Carefully adjust the band so that when evenly stretched the line *A* is just twelve inches from *B*, and mark the cloth, as before, where it passes over the edge of each stick. Shift the cloth again still farther around the sticks; this time let the lines *A* and *B* pass each other, and, when they are again separated just twelve inches and the cloth evenly stretched, draw pencil lines at the edges of the sticks as

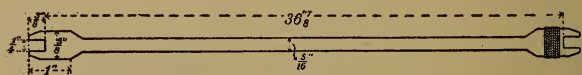


FIG. 4.—DIAGONAL STRUT.

before. Time and care spent in laying out these lines accurately on the cloth, so as to divide it into equal portions *when stretched*, will be well repaid in the even flying of the kite.

The cloth bands are now ready to be tacked to the sticks. Put one of the bands over the central truss and tack the line *A* down with five or six small (two-ounce) tacks to one of the sticks; for example, as shown from *a* to *b*, Fig. 2. The opposite line, *B*, must be tacked to the opposite stick from *c* to *d*. The remaining band is similarly tacked to the opposite end of the truss. Finally, the four corner longitudinal spines are passed within the bands, and the appropriate lines of the cloth tacked to the sticks. The only point needing special atten-

tion at this step is to arrange the corner spines so that their notches will stand in proper relation. Referring to Fig. 3, it will be recalled that the small notch at one end of each spine is nearer the end than at the opposite end. In tacking the spines to the cloth, all that is necessary is that one pair of spines in opposite corners shall have the notches the shorter dis-

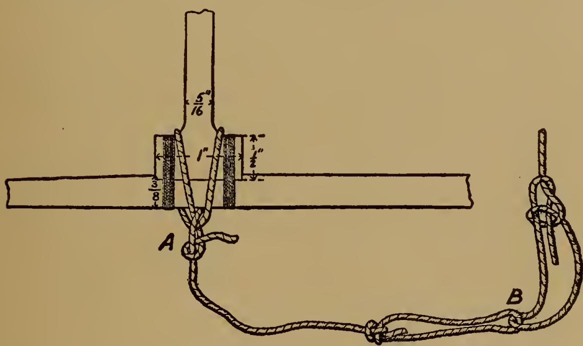


FIG. 5.—FIRST FORM OF BRIDLE.

tance from the end, and the notches of the other pair be at the longer distance. In other words, tack short-ended spines in the *C* and *D* corners, as they appear in Fig. 1; then the long ends of the remaining spines must occupy the *E* and *F* corners of Fig. 1. When so arranged, one diagonal strut stepped in the notches will pass in front of, and the other behind, the uprights of the central truss.

All that now remains to be done is to fit up the diagonal struts. Fig. 4 shows a finished diagonal strut. It is difficult to determine beforehand the exact length these should be, because the amount the cloth bands will stretch is uncertain. The length as indicated in Fig. 4 is about right, if all the other dimensions specified herein are carefully adhered to. Make up a pair of struts about a half-inch too long at first; by trying them in the kite and cutting out the notches deeper and deeper a perfectly satisfactory fit can be secured and the cloth braced out smooth and taut. Care must be taken to keep the two struts of the same pair the same length. To prevent the forks from splitting off, it is quite necessary to lash the ends just back of the notch with good, waxed thread. The diagonal struts are to be inserted within the cells of the kite, so that the notched ends enter the shallow notches of the corner spines, shown at *a* and *b*, Fig. 3. One diagonal strut passes in front of, and the other behind, the upright of the central truss in each cell, and the three sticks are firmly bound together at the point of crossing with waxed thread.

Two methods of bridling or fastening the string to the kite will be described. Cut off about six feet of stout cord and tie one end to

the central truss at *A*, as shown in Fig. 2, the cord passing through small holes pierced in the cloth covering. The knot employed at this point is shown enlarged at *A*, Fig. 5. The flying line should be tied to the free end of this cord by means of bowline knots, as shown at *B*, Fig. 5. This knot is strong, never slips,

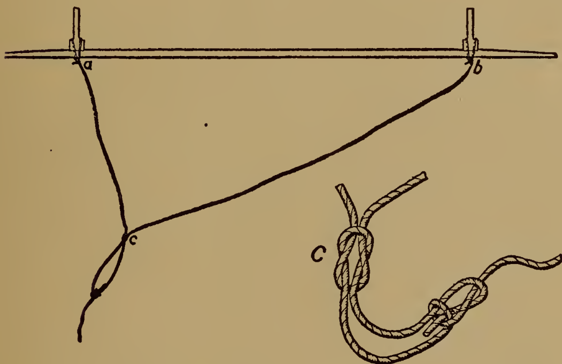


FIG. 6.—SECOND FORM OF BRIDLE: *C*, ENLARGED KNOT LOOSENED.

and can be easily untied, no matter how much the line may have been strained.

The one-point attachment of bridle, described above, is better suited to strong than light winds, and sometimes in lighter winds it may be more satisfactory to employ the two-point attachment of bridle shown in Fig. 6. In this the free end of the six-foot piece of cord is shown tied to the central truss at *b*, thus

forming the bridle, *a*, *b*, *c*; the main line being attached at the point *c* by a kind of knot shown enlarged at one side. This will not slip of itself, but the point of attachment can easily be adjusted as may be desired.

To be perfectly safe, the flying line for this kite should have a tensile strength of from fifty to sixty pounds, and be equally strong throughout.

If the wind is favorable for flying, the best way to start the kite in flight is to run out 150 feet or so of twine while the kite is held by an assistant. When all is ready, the assistant may toss the kite upward a little in the direction in which it is to go. It will take care of itself afterward. It is important that the kite be cast off directly in line with the wind, otherwise it may seem to dart badly. When fairly up, the kite may sweep a little from side to side, but if it ever darts or turns over, there is something radically wrong, probably due to an uneven distribution of the cloth surface, or some permanent distortion of the framework. Sometimes the weight of the wood varies, and one side is heavier than the other. This should be corrected by weighting the light side with a small strip of sheet lead, or otherwise.

If the wind is very light, a finer twine may be used in flying, and it may be necessary to

run a little with a long string out, in order to get the kite into upper and more rapidly moving currents.

When the wind is very strong, drop the ball of twine on the ground so that the cord can pay out rapidly, and let the kite go up directly and quickly from the hand.

CAPTAIN BADEN-POWELL FOLDING UP A BIG KITE.

SARAH BERNHARDT MAKING A PHONOGRAPH RECORD.

CHAPTER VII.

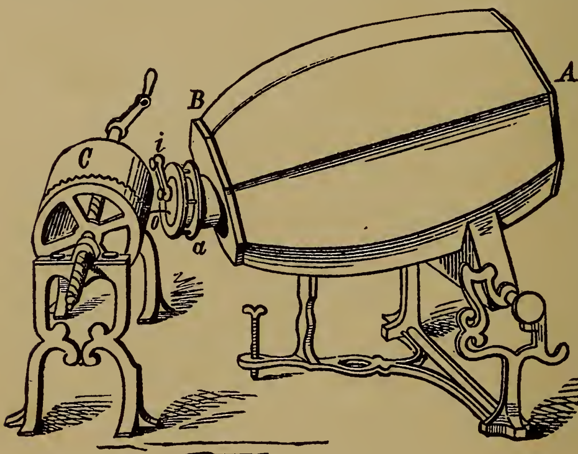
THE STORY OF THE PHONOGRAPH.

Making Pictures of Sounds and Sounds of Pictures.

This is the wonder of the phonograph: it is a machine which makes pictures of sounds, and then, at will, changes these pictures back into sounds again. A picture of a matchless solo by Melba is made in Paris on a little wax cylinder; the cylinder is sent through the mails to New York like any other picture, here to be transformed again into the voice of Melba, repeating all the sweetness and richness of the original tones. The voice of Nicolini, preserved in pictures, still sings, although the singer himself is dead. And this is something hard to realize, even at this day when the phonograph has become almost as familiar as the sewing-machine.

Every man has in his throat a delicate membrane which is set to quivering every time he speaks. The vibrations thus produced in turn set the air to quivering, and these waves roll through space, very much like the waves on

the seashore, until they strike on the drum or membrane of the ear. That is the way we hear; it is nature's telephone. If the vibrations are rapid we say that the voice is high;



SCOTT'S PHONAUTOGRAPH.

The first suggestion of a talking machine, in which the sound pictures were scratched on a cylinder covered with lampblack, by means of a hog's bristle.

if slow, we say that it is deep. Each note has its own different vibrations.

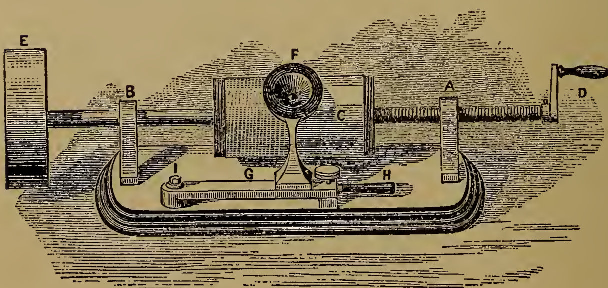
Away back in 1857 Leon Scott, knowing these simple facts in physics, conceived the idea of making sounds produce pictures. It was an idea as original as it was bold. In the experiments which followed, Scott constructed a curious little device called the Phonautograph, which vividly foreshadowed a part of the

operation of the phonograph. It consisted of a thin membrane—a bit of bladder—stretched tightly over a barrel-shaped frame. In the center of this membrane a stiff hog's bristle was firmly fastened. On speaking with the lips close to the outer end of the frame the membrane vibrated in accordance with the sound waves thus produced, the bristle moved back and forth and scratched a continuous wavy track on a revolving cylinder which had been well daubed with lampblack. This wavy line was an actual picture of the human voice. But it was a mere laboratory experiment, and no one even dreamed that such a sound picture could be again transformed into speech—until the idea came to Thomas A. Edison with the suddenness of inspiration.

It was in 1877, long before Edison had become widely famous. At that time his experiments were carried on in a shop in Newark, New Jersey, where he was surrounded with a little company of trusted workmen. It was at the time when Edison often became so absorbed in his schemes for inventions that he forgot his meals, and frequently worked night and day for two or three days together, keeping all of those about him as busy as he was himself. Sometimes he would call in an organ-grinder to keep the men awake and cheerful until the

strain was over, and then he would hire a boat and take all hands down the bay with him on a fishing excursion. It was with this singleness of purpose and loyalty that Edison and his men always worked together.

Not long ago I visited Edison's great laboratory at Orange, New Jersey, where more than seven hundred men are employed in coining the visions of the master's brain. I found



EDISON'S FIRST PHONOGRAPH.

Edison himself sitting in one of his characteristic positions, half leaning upon a table filled with drawings, his head on his hand and his fingers thrust through his hair. He told me briefly how he came to invent the phonograph, and his story was later much extended by John Ott, who was with him through all of the experiments.

The inventor had been working during the early part of the year 1877 in developing and

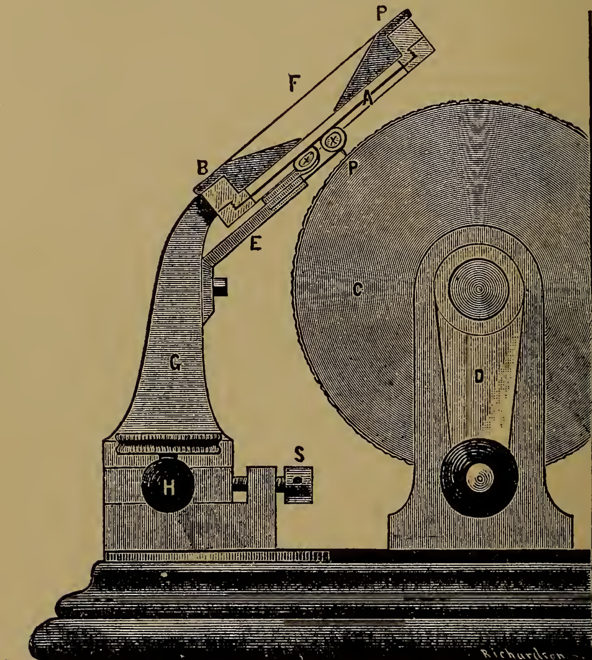
improving the telephone, inventing the transmitter which has since borne his name. This consisted of a disk of carbon, having a sharp-pointed pin on the back of it. He had noticed many times that when he spoke against the face of the disk the vibrations would cause the pin to prick his fingers or to indent any soft substances held near it. This was one fact; he carried it in mind, but it gave him no particular suggestion. It was, indeed, only a step beyond Scott's discovery.

Previous to this time Edison had invented a remarkable device for the automatic repetition of telegraph messages. It consisted of a simple apparatus by means of which the dots and dashes of the original message were recorded in a series of indentations on a long, narrow strip of paper. This record could be fed into a sending machine and the message re-transmitted without the service of an operator. In other words, Edison had made pictures on paper of the sounds communicated over the telegraph wires, thereby approaching the phonograph from another direction.

"In manipulating this machine," Edison wrote in 1888, "I found that when the cylinder carrying the indented paper was turned with great swiftness it gave off a humming noise from the indentations — a musical, rhythmic

sound, resembling that of human talk heard indistinctly."

Here was another fact—unconnected as yet,



CROSS SECTION OF EDISON'S FIRST PHONOGRAPH, SHOWING METHOD OF OPERATION.

but exceedingly important as pointing to the great discovery.

"I remember," John Ott told me, "that Edison had been working at his bench in the laboratory nearly all day, silent for the most

part. Quite suddenly he jumped up and said with some excitement: 'By George, I can make a talking machine!' Then he sat down again and drew the designs of his proposed machine on a slip of yellow paper. I don't think it took him above ten minutes altogether."

On the margin of that design Edison marked "$8," and handed it to his foreman, John Kruesi.

"My men all worked by the piece in those days," Mr. Edison told me, "and when I wanted a model made I always marked the price on it. In this case it was $8, I remember. Kruesi went to work at it the same day, and I think he had it completed within thirty-six hours. We used to try all sorts of things, and most of them were failures; so that I didn't expect much from the new model, at least at first, although I knew it was correct in principle."

But Kruesi fitted the tin-foil on the cylinder, and brought the machine to Mr. Edison. The inventor turned the handle and spoke into the mouthpiece:

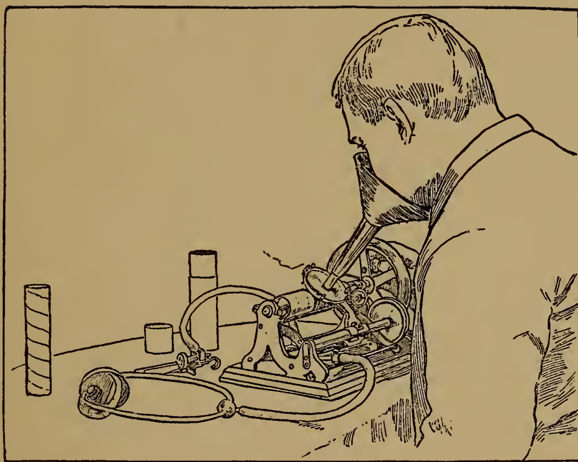
"Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go."

Then he set the recorder back to the starting-place and began to turn the cylinder. At the very best he had not expected to hear more than a burring confusion of sounds, but to his astonishment and awe the machine began to repeat in a curious, metallic, distant voice:

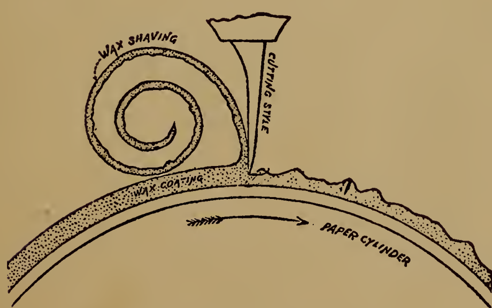
"Mary had a little lamb . . ."

And thus the first words ever spoken by a phonograph were the four simple lines of Mother Goose's melody. The idea had come to the inventor with a flash of inspiration, and the machine had proved its marvelous possibilities on the first trial. Few inventions ever have been conceived and carried to success so swiftly. Kruesi's eight-dollar machine, which could not now be bought for hundreds, is in the patent museum at South Kensington, London.

This first machine, although it talked, was a very crude affair compared with the all but perfect phonographs of to-day. In principle it was exceedingly simple. There was a diaphragm or membrane, having a sharp-pointed pin attached to its under surface. When sound waves, caused by a spoken word or a piece of music, struck this diaphragm, it vibrated, and the pin rose up and down. The cylinder on which the sound pictures or records were to be



MAKING A RECORD ON ONE OF THE EARLY FORMS OF THE GRAPHOPHONE.



SHOWING HOW THE RECORD IS ENGRAVED ON THE WAX CYLINDER—MUCH ENLARGED.

made was covered with tin-foil. At every vibration of the pin, indentations of various depths were made in this tin-foil. These little holes were so small as to be scarcely visible to the naked eye, but when the diaphragm was set back to the beginning and the cylinder was turned, the pin, travelling up and down over the rough road of indentations, caused the diaphragm to vibrate and give out the same sounds which had been previously spoken into it. A reference to the pictures on pages 254 and 256 will show clearly just how the machine worked. *A* is the plate or diaphragm, 1-100 of an inch thick, which vibrated when spoken against, driving the point *P* into the cylinder *C*. *F* is the mouthpiece, and *D* the crank by means of which the cylinder was turned.

Few inventions ever awakened a world-wide interest more suddenly than did this of the phonograph. When it was first exhibited in the "Tribune" building in New York, every scientific paper, every magazine, and every newspaper in this and in foreign countries gave accounts of the invention, and dealt with its dizzying possibilities. Edison himself wrote an article for the "North American Review," in which he told of some of the marvelous uses to which the machine would be put in the future.

PREDECESSORS OF THE GRAPHOPHONE.

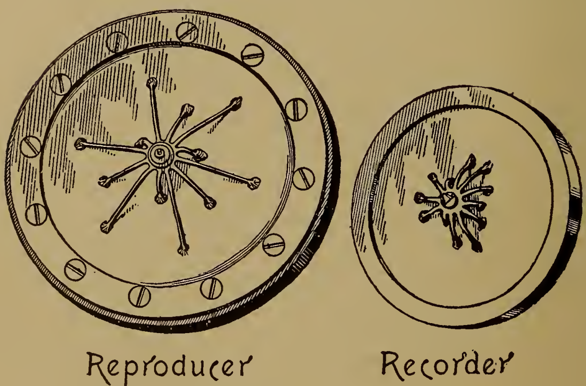
Talking machines, one for recording and the other for reproducing sounds, as invented by Alexander Graham Bell, Chichester A. Bell, and Professor Sumner Tainter of the Volta Laboratory Association.

Edison patented his invention both in the United States and abroad, and manufactured a considerable number of machines, chiefly for use in college laboratories. Then he became deeply interested in a series of experiments with incandescent electric lights, and the phonograph dropped out of his mind for many years.

In the meantime Alexander Graham Bell, the inventor of the telephone, had received the most distinguished honor that can come to an inventor—France had bestowed upon him the Volta prize, an honor instituted by Emperor Napoleon the Great. It had been awarded only once before—to Faraday—and it has never been awarded since. With the money portion of the prize, amounting to 50,000 francs, Mr. Bell conceived the idea of forming an association for the advancement of the science of sound. To this association, composed of himself, Dr. Chichester A. Bell, and Charles Sumner Tainter, he gave the name "Volta Laboratory Association." From 1881 to 1885 these three men labored hard upon improvements in the method of recording and reproducing sound, finally producing a machine differing from Mr. Edison's in that it *engraved* the sound pictures on a cylinder of wax instead of *indenting* them on tin-foil, a very great and

important change, which enabled them to reproduce speech and music in a wonderfully lifelike manner. This machine was called the *graphophone.*

Another machine, the *gramophone*, was invented by Charles Cros, a Frenchman. In this device the record is scratched on a metal



BETTINI SPIDER DIAPHRAGM ATTACHMENT.

For making and reproducing difficult records.

cylinder which has first been daubed with a waxy substance. The cylinder is then taken out and immersed in acid. Where the recording stylus has scratched the wax away there the acid does its work, etching in the solid metal the wavy sound pictures left by the stylus. The sounds are then reproduced as in the other machines.

In later years Mr. Edison and Mr. Bell have made many improvements in the talking machine until it has reached its present perfected state.

Other important additions have been made by Lieutenant G. Bettini. Bettini discovered that all parts of the glass diaphragm used by Mr. Edison did not vibrate equally when spoken against. For instance, the center might vibrate at one speed and the sides at another, thereby producing the peculiar metallic or "tinny" effect which makes many phonograph records disagreeable. Consequently, instead of attaching the recording point directly and firmly to the center of the diaphragm, Bettini used what he called a "spider"—a little frame having several legs, the feet of which rested against the diaphragm at many different points, thereby making the diaphragm sensitive to every variety of sound, even high soprano voices, which have been exceedingly difficult to record. Bettini uses a diaphragm of aluminum instead of glass.

The sound pictures or records of the phonograph are now engraved on a wax cylinder with a fine stylus, the point of which is a bit of sapphire. After one record is made it can be readily duplicated. The old-fashioned ear tubes are giving way to horns, which bring out

the sound more distinctly, and distribute it over a whole room. When one record is worn out—and it can often be used more than a hundred times—the wax is shaved down and the cylinder is ready for another impression. Most of the modern talking machines are operated by clock-work, although some are fitted to run by electrical power, or even by foot-power like a sewing-machine. The prices vary from five dollars well up beyond a hundred dollars.

One of the most interesting things in connection with the phonograph is the new profession of record-making—for a real profession it is. At Mr. Edison's laboratory in Orange, New Jersey, a whole building is devoted to the production of singing cylinders, instrumental music, band music, solo, and speaking cylinders. A curious and wonderful place it is. In one little room shut off from all the others by tight doors I saw a man seated on a tall stool. He was talking and laughing uproariously in Yankee dialect into the flaring end of a long tin tube. At the other end of this tube there was a phonograph with a boy about twelve years old watching the cylinder to see that the stylus was doing its work. The speaker, who had his coat off and was perspiring profusely, would first announce himself: "A humorous sketch, entitled 'Uncle Eben in

IN A PHONOGRAPH RECORD ROOM—MAKING A RECORD OF BAND MUSIC.

From a photograph loaned by Frank A. Munsey.

Fifth Avenue,' by the well-known comedian ——,'' and then he would begin his talk with no audience but the tin tube and the boy, who looked vastly bored. In another room there were several phonographs placed close together on a shelf, with their horns grouped around a slim young man, who was playing a lively jig on a banjo. Close behind him loomed the back of a piano, upon which a companion was playing an accompaniment. In still another room two men and a woman were singing a church anthem into the receiving horn of a phonograph. Their heads were close together, and both the men had their coats off, it being a hot day. Behind them on a pair of saw-horses stood a piano, which was being played with the utmost unconcern. If I had closed my eyes I certainly should have thought that I was sitting in church, and that the anthem was coming from the choir loft. When a record is finished it is taken out and repeated to see if it is correct, and the players or talkers gather around to hear their own words. If the cylinder is a success it is duplicated many times, and placed in the regular library of the phonograph, ready to go out to the users of the machines in different parts of the country.

And yet records of this sort are not always successful. Not every one can make a first-

class phonograph record. Some there are whose voices are too soft to make distinct impressions in the wax. The best voice is one that is almost metallic in its timbre—even harsh and hard. For the same reason a cornet makes a far better record than a guitar ; a piano, from its sharp and ringing tones, is better than a violin. In this way the phonograph has developed its own especial singers and players. Some soloists and talkers, who have never been able to make a success on the stage, have earned a peculiar and valuable reputation of their own among the users of phonographs. They may be as awkward as they please or as unprepossessing of manner or of face—if only they sing so that their voices come out clearly and beautifully from the little wax cylinders, their fame is made. And some of these singers and players earn very large sums of money. They receive, in general, one dollar for every song they sing or every "piece" they speak, and they often make from twenty to fifty records in a day.

In Mr. Bettini's studio more attention is given to voice records of famous men and women. Here Sarah Bernhardt came and talked into the phonograph, and here Campanari, Ancona, Plançon, and other singers equally famous, have sung. Here, too, you

A DUET WITH ACCOMPANIMENT.

From a photograph loaned by Frank A. Munsey.

may hear the voice of Mark Twain talking out with beautiful distinctness. Indeed, through this means, a famous man's voice may become as familiar as his picture, and it may go on

ONE OF THE NEWEST TALKING MACHINES.

talking and giving pleasure to the world long after the man himself is dead.

Recently a phonograph with a large-sized cylinder has been constructed for making unusually clear records. This improvement was

suggested by Thomas H. McDonald, and one wonders that no one thought of trying it before, since the principle of the improvement is simplicity itself. The surface of the large cylinder moves much more rapidly than the surface of the small cylinder, and the groove cut by the recording stylus is much longer. That is, the stylus, instead of making a series of abrupt holes in the wax, as it does when the cylinder moves slowly, scoops out long hollows with sloping ends. There being no sharp crests or holes in the groove, the reproducing ball follows every gradual ascent and descent, and does not leap from crest to crest, blurring the sound, as in the case of some of the smaller cylinders.

This new style of cylinder has been found to be especially valuable for recording the music of a full brass band or of an orchestra, and some exceedingly fine and popular records of this sort have recently been made. But of all phonograph records, jolly negro and comic songs are the most popular. Next to them come instrumental solos, and after that church chimes, quartettes, and so on. Recently a set of cylinder records have been made to play dance music, and at the same time to call the figures, so that for a small dancing party no regular musicians are needed.

Another very wonderful development of the phonograph which is now in course of evolution is the reproduction of entire operas. Not long ago Mr. Edison had a portion of the opera of "Martha" performed before one of his kinetoscopes; he succeeded in taking 320 feet of pictures. The acting of the opera can now be thrown in lifelike moving pictures on a screen, and at the same time the phonograph may sing the music which goes with each scene, so that together a portion of the opera will be completely reproduced—a marvel which could not have been imagined even ten years ago.

It has been found that the phonograph will "hear" and record sounds too high and too low to reach the human ear. The very deepest tones to which our ears will respond have sixteen vibrations to the second, whereas the phonograph will record down to ten vibrations. And then, more wonderful than all, the pitch can be raised until we hear a reproduction of these low sound waves—until we hear the unhearable.

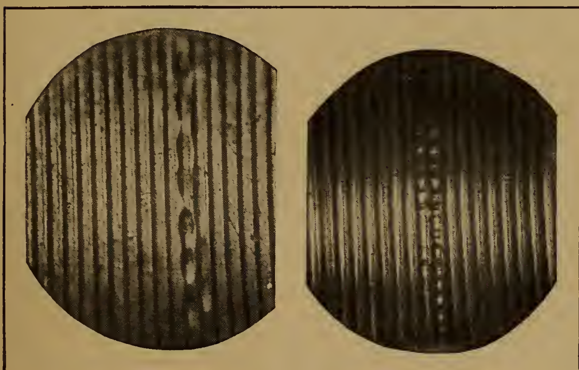
Within the last few years the phonograph has developed many curious and important uses. It has been employed with success as a teacher of languages. It reproduces perfectly the words and accents of a foreign tongue so that a student may hear the difficult inflection

repeated over and over until he learns it, without a living teacher. Indeed, whole lessons, including the meanings of the various words and any necessary explanations, can be talked into the phonograph without the least difficulty. In similar manner the phonograph has

A MODERN HIGH-CLASS PHONOGRAPH.

been used for teaching small children their lessons, and in one case that I know of a minister actually preaches his sermons first into a phonograph and then sits back and listens to his own words as if he were a member of the congregation, noting the mistakes in delivery, and at

the same time committing the sermon to memory. In many scores of business offices the phonograph is used exclusively for purposes of dictation. The machine is frequently placed in a drawer of the desk, so that whenever the business man wishes to dictate a letter he merely opens the drawer, starts the machine,



A PHONOGRAPHIC RECORD.

How a line of the song "She was Bred in Old Kentucky" looks on a wax cylinder.

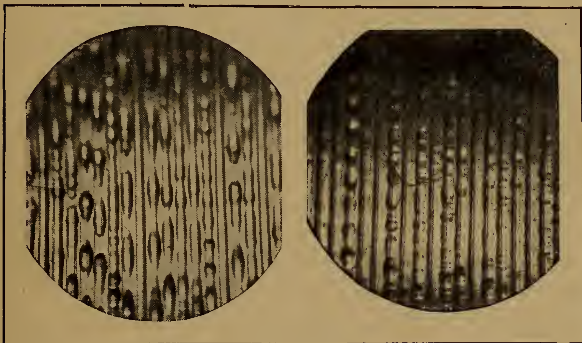
talks as long as he wishes, and then stops the cylinder. In this way he does without the services of a stenographer. At any time during the day the typewriter girl may come and take the record away, place it in her machine, insert the tubes in her ears, and copy the letters which the business man has dictated. In this way both may work without interruption.

Several busy men in New York have phonographs in their offices into which visitors who call during their absence may tell of their errands. A phonograph in a restaurant or a barber shop has long been a popular attraction, and I have known of a phonograph being used by a newspaper writer for dictating his articles. Two St. Louis inventors have recently suggested the use of phonographs in place of the whistling buoys on dangerous shoals. One of these inventors says:

"We intend to place one of our phonograph buoys on the noted Kitty Hawk reef at the mouth of the Savannah River. At present a bell buoy marks that dangerous reef, and you know the action of the waves tolls the bell of the buoy. It will doubtless surprise many vessel captains to hear our buoy, with its clear, distinct sound, say, 'I am Kitty Hawk, Kitty Hawk,' and they will hear it farther than they can hear the bell buoy."

Many years ago Mr. Edison suggested the use of phonographs for recording the works of the greatest writers of fiction. He himself dictated a considerable extract of "Nicholas Nickleby" into a phonograph, and he found that six cylinders, twelve inches long and six inches in diameter, would hold the entire novel. Think what a boon such records would

be to a blind man, or, indeed, to a man who comes home with worn-out eyes from a long day's work in the office. The phonograph could talk off the story without a break, and if it had been dictated with expression and



ANOTHER VIEW OF "SHE WAS BRED IN OLD KENTUCKY."

The records are here very much enlarged. That on the left shows the sound pictures on a rapidly revolving large-sized cylinder of the McDonald pattern. That on the right is one of the ordinary records, showing how much more abrupt the indentations are.

spirit, the effect would be that of listening to a good elocutionist.

And thus the phonograph has become a great factor in promoting the pleasure of the race as well as in assisting it with its work. The wonder of the invention—a machine which talks like a man—is yet new enough to make us feel as the famous Emperor Menelek of Abyssinia did when he first heard the phono-

graph. After the recent victory in the Soudan, Queen Victoria spoke a message of friendship and good-will into a phonograph. The royal words were delivered one Sunday afternoon, the phonograph working perfectly. The Queen's voice was produced with great clearness, and Menelek insisted upon hearing the message repeated many times. First he would listen to it as it came from the trumpet, then he would use the ear tubes. And when it was over he relapsed into silence, and then ordered a royal salute to be fired, while he stood in solemn wonder before the strange machine that talked.

THE TALLEST BUILDING IN THE WORLD.

Park Row Building, New York City, twenty-nine stories high.

CHAPTER VIII.

THE MODERN SKYSCRAPER.

Story of the Tallest Building in the World.

"A STEEL bridge standing on end, with passenger cars running up and down within it."

This is the engaging definition of a "skyscraper" given me by an architect who is as famous for his quaint conceits of speech as he is for his tall buildings.

It seems odd to speak of any building as a new invention, since there have been buildings almost as long as there have been men; and yet the very fact—and curious enough it is when you come to think of it—that the skyscraper is truly more a bridge than a building, and that cars do actually run on perpendicular tracks within it, makes it not only one of the latest feats of the inventor, but one of the very greatest. For thousands of years every large building in the world was constructed with enormous walls of masonry to hold up the inner framework of floors and partitions. It was

a substantial and worthy method of construction, and there seemed no need of changing it. But one day a daring builder with an idea astonished the world by reversing this order of construction, and building an inner framework strong enough to hold up the outside walls of masonry. The invention was instantly successful, so that to-day the construction of a tall building is "not architecture," as one writer observes, "but engineering with a stone veneer."

Ten years ago, in 1889, there was not a "sky-scraper" in the world; to-day there are scores of them in American cities, the heights varying from seven stories up to thirty, making them by all odds the greatest structures reared by the hand of man. The idea of constructing a building like a bridge is said to have originated in Chicago; it has, indeed, been given the name "Chicago construction." Some of the earliest buildings embodying the steel-cage idea were the Tacoma (completed in 1889), the Home Insurance, and the Rookery buildings of Chicago, and the Drexel Building in Philadelphia. Nearly all of these were constructed in spite of the opposition and prophecies of failure of scores of experienced builders, often including the building commissioners who issued the permits.

Every invention has its reason for being.

REALTY BUILDING, PHILADELPHIA, AS IT LOOKED JULY 30TH.

First of a series of pictures taken every two weeks from July 30th to November 5th, showing the remarkable rapidity of construction of a modern skyscraper.

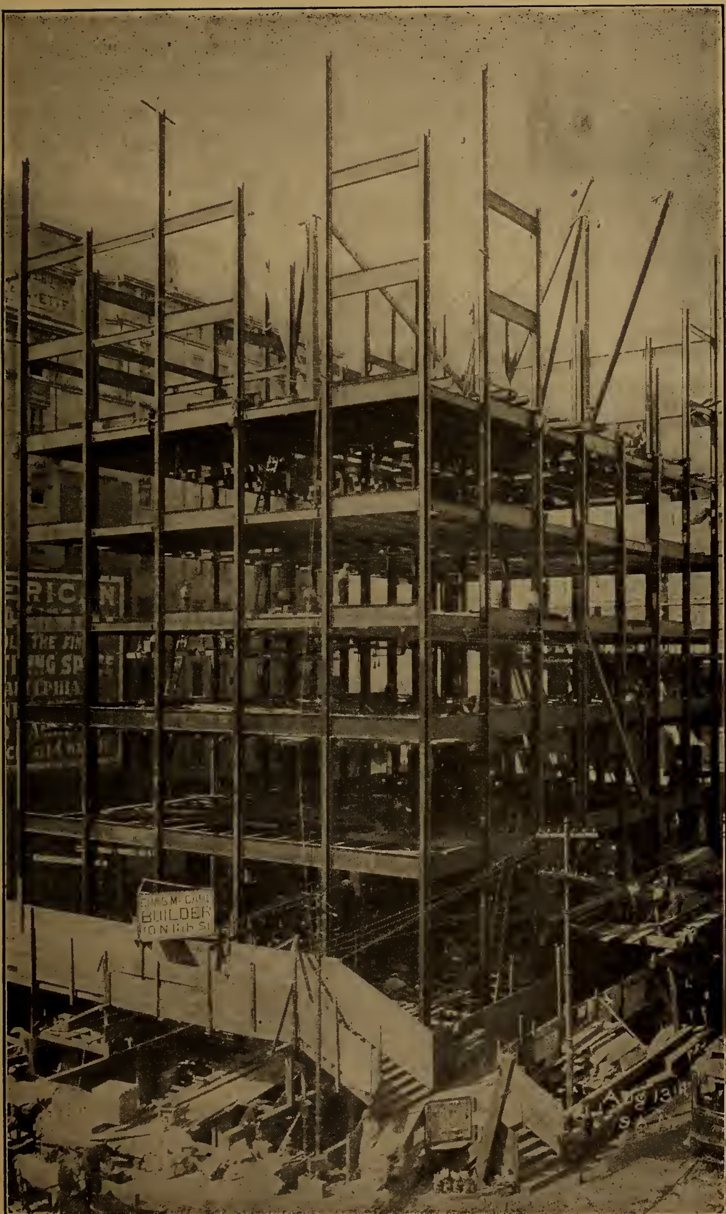
Unless it is needed, it does not appear. So with the skyscraper. Great cities had grown with a rapidity unknown anywhere in the world; business centres were much overcrowded; progressive professional men wished to be within easy reach of the districts where money was making fastest. Property owners said: We can't spread out, so we must go up. In New York single acres are worth more than $7,000,000. Land of this value covered with buildings of ordinary height could not be made to pay; again the conclusion was resistless: We must go up. Moreover, engineering and the various processes of steel construction had been advancing at great strides; steel was comparatively cheap, and a light skeleton framework cost less in the beginning and required less room than immense masonry walls. And, lastly, and by no means of least importance, the modern elevator had been invented. I remember once of talking with a grizzle-headed elevator man in what is now an old skyscraper. He had evidently done some quiet thinking as he travelled up and down, year after year, on his perpendicular railroad.

"Did you ever think," he asked, "that skyscrapers would be an impossibility without elevators? It's a fact. Nothing above seven or eight stories without 'em. You'd never catch

any business man climbing eight flights to his office."

And yet if the elevator has made the skyscraper a possibility, the skyscraper has in no less degree developed the elevator; both have gone up together, and both would seem to have approached very near to perfection.

The building of a modern skyscraper is a mighty task, full of difficult problems, more difficult even than those connected with a great steamship, a great bridge, or even a railroad line. Knowing how far the building is going up, the architect must determine from the character of the ground on which it is to stand how far it must go down. In New York many of the greatest buildings have foundations so deep that they rest on the solid rock, seventy-five feet below the surface, and there are two or three stories beneath the street, as well as twenty or thirty above. In Chicago all of the great buildings rest on what may reasonably be called flat-boats. Indeed, Chicago is a floating city—floating on a bed of soft sand and mud. These boats are made of great timbers, driven straight down, or else of steel rails or steel girders laid criss-cross and filled in with cement until they form a great solid slab of iron and stone. And as might be expected, these boats frequently tip a little to one side, so that many



REALTY BUILDING, PHILADELPHIA.

As it looked August 13th. *(See page 285.)*

of the greatest skyscrapers are slightly out of plumb, like modern towers of Pisa, although they do not lean enough to be at all dangerous. I remember distinctly how a keen-eyed newspaper man made the discovery that one of the most famous skyscrapers in the world—and one of the largest—was out of plumb. He was in the sixteenth story of the building across the street. The doctor who occupied the room had tied a weight to a window cord in order to keep the shade well down, thus making it a plumb-bob. It so happened that the newspaper man glanced along this cord and across the street to the corner of the great building opposite. At first he couldn't believe his eyes; the cord was certainly plumb, or else all the school-books were incorrect; therefore the building must certainly be leaning to one side. He called several friends, and each of them bore him out in his observation. He rushed off in great feather, secured an engineer, and had careful measurements taken. The building was found to lean nine inches to the eastward at the top, and there was a news "beat" in one of the newspapers the next morning.

All great buildings are expected to settle, and the main effort is to make this settlement uniform throughout. In New York the tall buildings which rest on a foundation of fine

wet sand have all settled from one-quarter to nine-sixteenths of an inch. The Marquette Building, Chicago, and the St. Paul Building, New York, have provisions made at the bases of their columns for lifting them up with powerful hydraulic presses and inserting packing of steel should they settle too much.

And thus it will be seen how difficult and delicate a problem the builder must meet in securing a solid foundation for the end of his bridge which goes into the ground. He must know, not only just how much the entire building will weigh, almost to the ton, but he must know the weight of each part of it, so that the load may be equally distributed over the foundation, thereby preventing any tendency to tip over. He must also compute the "live" weight which his building is expected to carry, that is, the furniture, the safes, the tenants themselves. And in Chicago, where the foundation is clay, he must not put a weight of more than one and one-half to two tons on every square foot of surface; the solid rock of New York will bear more. Moreover, he must determine exactly how much strain each steel girder, each column, even each rivet will bear. If he overloads any single girder, he endangers his whole building. Then he must calculate how much wind is going to blow against his

THE FIRST FLAG AT THE SUMMIT OF REALTY BUILDING.

As it looked two weeks later, August 27th. (*See page* 285.)

building, and from what direction most of it is coming; he must even calculate on the pounding of horses' hoofs and heavy wagons on the pavement outside; he must make provisions for supplying water to the top stories, where the city cannot pump it; he must provide amply against possible fires—and that's one of the most difficult of all the problems ; he must see to the prevention of rust in his steel work ; he must secure proper ventilation and lighting, so that every room has its windows with a street front if possible; and, more difficult than all else, he must keep well within the hampering limits of the city's building laws. These are only a few of thousands of intricate details, not to consider the tremendous question of cost with which the builder must grapple. And then it sometimes happens that he is blamed if he does not make this tower of steel, with its hundreds of rectangular windows, a thing of architectural grace and beauty.

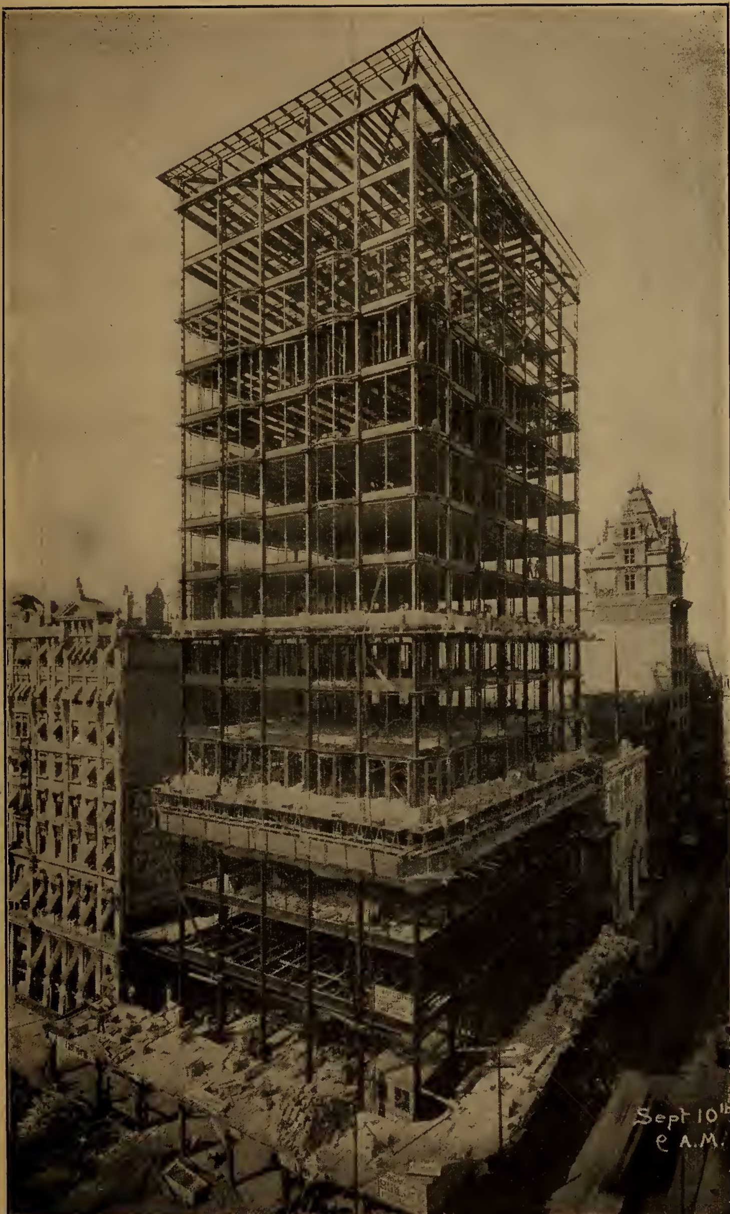
Perhaps it will be possible to give the best idea of what a modern skyscraper really is, when completed, by relating some of the important facts concerning what is now the greatest modern building—indeed the tallest inhabited building in the world—the Park Row Building in New York City. It was designed by R. H. Robertson, and it stands as one of

the greatest monuments to the daring and enterprise of the American builder. It can be seen from far out in New Jersey, from Staten Island, from Long Island, and the lookout of every ship that enters the harbor sees it looming like a huge tower above its neighbors.

To begin with, it has twenty-nine stories, and its height from the sidewalk to the tops of the cupolas on the towers is 390 feet. Thus it is over 100 feet taller than the dome of the Capitol at Washington, and 85 feet above the Statue of Liberty. Even these figures do not represent its full proportions. The flagpoles on top of the building are 57 feet in height. The foundations extend 54 feet below the surface. Therefore, from the base of its foundations to the top of its flagpoles the new building spans 501 feet, or nearly the tenth of a mile, exceeding by 48 feet the extreme height of the Pyramids.

The restaurant on top of the main building is 308 feet above the street, while the topmost offices—and they are all large, comfortable rooms—are 340 feet in air. Their windows command a view of over 40 miles.

The new building has a frontage of 103 feet on the street which it faces, of 23 feet on a side street, and of 47 feet on a rear alley. It may therefore be said to look in three directions.



FIRST STONEWORK, SIXTH AND NINTH STORIES, REALTY BUILDING.

As it looked September 10th. (*See page* 285.)

It is nearly four times as high as its main frontage. The difficulty presented by that proportion is an architectural problem of some magnitude in itself.

It need not be said that a vast amount of steel and stone, glass, and other material enter into the construction of such a building. As a matter of fact, the building weighs about 20,000 tons. The material of which it is constructed would build all the houses of an ordinary suburban town, with enough left over to construct a good-sized church.

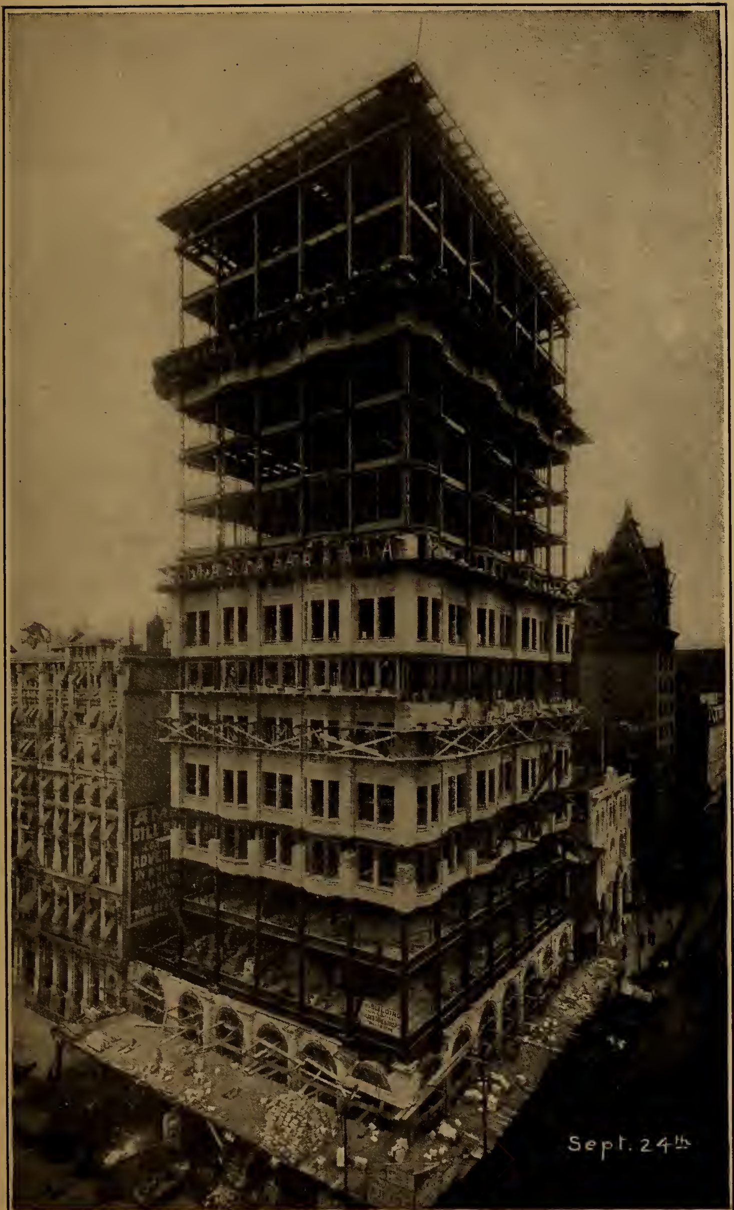
As with all skyscrapers, the foundation of the Park Row Building is its most interesting, as well as its most perplexing, feature. Several acres of Georgia timberland were denuded to furnish the 1,200 great pine piles, some of them 40 feet long, which were driven into the sand of the site. These piles are in rows, two feet apart, under the vertical columns which support the building. They were driven into the ground as far as they would go under the blows of the one-ton hammer. They are thus prepared to sustain a weight of 20 tons, although the most that will be put upon them is about 16 tons, a margin great enough to give any builder a sense of safety. Moreover, they are below the water-line, so that they are indestructible by the ordinary process of decay.

When the piles were driven as far as possible their tops were cut off, and the sand was cleared away for a foot down around their tops and concrete was poured about them, forming a solid rock surface resting securely upon their tops. On this concrete base were laid large blocks of granite, and above them the brick piers of the building.

The weight of the building is not allowed to come directly upon the granite capstones which surmount these piers. Instead, it is distributed by the system of steel girders, some of them 8 feet in depth and 47 feet long. These are in effect big bridges placed between the foundations and the footings of the vertical columns to distribute the weight evenly. The heaviest girder in the building, which lies deep beneath one wall of the building, weighs over 52 tons.

Above the surface the building is a mere steel framework—a big steel box—built like a cantilever bridge. The walls are comparatively light, being hardly more than thin sheeting for the skeleton, and, curiously enough, the stonework of the second and some of the higher stories was constructed before the wall foundations were laid, being entirely supported by the steel framework.

As I said before, the dead weight of the building itself is about 20,000 tons. But with



RUSHING THE STONEWORK ON FOUR FLOORS AT ONCE.

The Realty Building on September 24th. (*See page* 285.)

the addition of the maximum load which the twenty-nine floors are calculated to carry, the total weight of the structure will amount to something like 61,400 tons.

There are 950 rooms in the building. Counting four persons to each office, this will make the permanent population of the building nearly 4,000, or equal to that of many a flourishing county seat. To this must be added a large transient population amounting probably to one person for each resident at any given time during business hours. This would make an ordinary population, resident and floating, of 8,000 for this one building! If twenty persons visit each office during the day, there would be 27,000 persons using the building every day. The various elevators have daily passenger traffic of over 60,000, or more than that of many an important railway line.

It is a curious reflection that if the regular occupants of the building were placed shoulder to shoulder on the ground that it occupies, there would be barely standing room for them; while if all the persons who visit the building during a day were gathered on the ground site at one time they would make a group standing five feet deep on one another's heads.

The cost of the building was $2,400,000, but it will collect more in revenues every year than

many a populous county. If a building as high and as large could have been constructed by the old solid masonry process, it would have cost fourteen times as much, and the walls would have been so thick at the base that there would have been little or no room for offices and stores.

The time may come, and come soon, when buildings higher even than this one may be built. There is nothing in the engineering problem to prevent the construction of a fifty-story building, but such a sight will probably never vex the eye of man. Already various American cities are passing laws limiting the height of buildings. Moreover, many property-owners feel that time should be given to ascertain how the skyscraper will endure—whether the steel will weaken with rust, whether the foundations will hold true, whether the fire-proofing is efficient. Most skyscrapers are only a few years old; but examinations of steel columns erected ten years ago and housed in cement, and of foundation beams lying below the water-line, have shown that not even the blue-black scale from the rolling-mill finish has turned color. Wherever it is possible, these steels are buried in cement, in itself a rust-proofing, and under such conditions the steel-constructed building promises to stand as long

STONEWORK COMPLETE FIRST IN THE MIDDLE OF THE BUILDING.

The Realty Building as it looked October 8th. (*See page* 285.)

as the building itself shall be satisfactory to its owner and its tenants.

A great office building is really a city under one roof. It has its own electric-lighting plant and sometimes a gas plant in addition; it has its own water-works system, with a big stand-pipe at the top to supply the upper floors, and sometimes an artesian well underneath; it has its own well-drilled fire department, with fire plugs on every floor, and hose-lines and chemical extinguishers; it has its own police department, for every great building is now supplied with regular detectives who watch for petty thieves and pickpockets, and prevent peddlers and beggars from entering their domain. It is even governed like a city; for the superintendent is the mayor, and he has a large force of workmen always busy cleaning the streets and stairways of the big structure. In some of the Chicago buildings, where a peculiar glazed terra-cotta brick is used for sheathing, the walls are washed outside as well as in. In its elevators it has a complete system of electric railroads, and a very wonderful and intricate system it is, too, with automatic arrangements for opening and shutting doors, for indicating exactly where the car is in its ascent and descent, and for preventing accidents from falling. And there is in many of the greatest

buildings a complete express service of cars, some cars not stopping below the tenth or some other skyward floor. A number of buildings there are that have their own telephone system as well as connections throughout with city lines, their pneumatic-tube parcel and message delivery systems, and at least one has a network of pipes conveying compressed air for power, while every great skyscraper is provided with one or more telegraph, cable, and district messenger offices, so that a tenant sitting at his desk can send a message almost anywhere on earth by merely pushing a button call for a messenger. In the modern mail-chute—a long glass and iron tube through which a tenant on any floor may drop a letter to the big box in the basement—the skyscraper has its own mail system. A young Englishman, a friend of mine, who was on his first visit to New York, stood for half an hour watching the letters flit downward through one of these glass tubes.

"That is the most wonderful thing I've seen in America," he said; "that, and the little tube with red oil in it which tells when the lift is coming."

Many of the modern buildings now have a bathroom on every floor, a regular barber-shop, a restaurant on the roof, a stand where the latest newspapers and magazines, cigars

ROOF-BUILDING ON THE REALTY STRUCTURE.

As it looked October 22d. (*See page* 285.)

and candies may be obtained, with frequently a library to which a tenant may go when looking up references or to while away an idle half-hour. In the basement there is frequently a safety-deposit vault and a place for storing

DETAIL OF STEEL SKELETON WORK, SHOWING HOW A BIG BUILDING IS BRACED AND RIVETED TOGETHER.

bicycles; on the first floor, a bank where a business man may keep his money; and somewhere up at the top, not so frequently, a social club. And of late some of the great buildings have actually been provided with bedrooms and bachelor apartments, so that a tenant may sleep near his offices if he is busy. Indeed, a

man might live in a modern skyscraper year in and year out, luxuriously, too, with every want richly supplied, and never pass beyond the revolving storm doors at the street entrance.

As to the future of the skyscraper no one knows definitely, but all the architects proph-

JOINING OF BEAMS AND PILLARS.

esy greater beauty. They are learning how to treat these great slim towers so that the effect is pleasing to the eye. In times past the necessity of a façade from 250 to 350 feet high has often resulted in the bold, staring resemblance to a chimney, which is both ugly and painful to the sight. But the architect is learning to

READY FOR INSIDE FINISHING.

The Realty Building on November 5th. (*See page* 285.)

SHOWING IMMENSELY STRONG SKELETON WORK OF A TALL AND NARROW BUILDING IN BOSTON.

INTERIOR "WELL" OF A SKYSCRAPER LOOKING UP.

A photograph taken from the bottom of a tall building toward the top.

relieve this tendency by treating the stories in groups of four or five. This lessens the effect of extreme height. At the same time the width is made to seem greater than it really is by the addition of heavy cornices and projecting balconies.

While it is perhaps too much to expect that a skyscraper shall become an object of beauty, these various devices do much to give the building personality and distinction, and perhaps this is as far as the architect ever can go.

PROFESSOR LANGLEY'S AËRODROME IN FLIGHT: A VIEW FROM ABOVE.

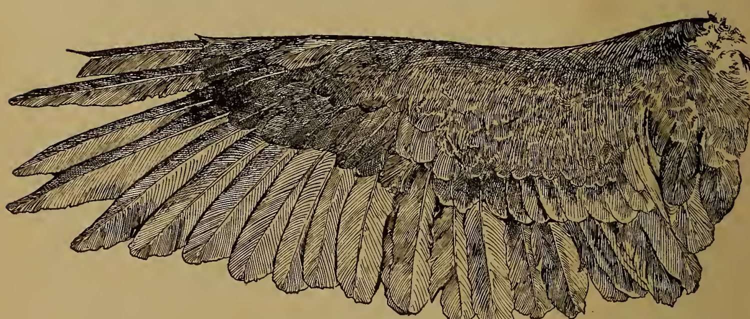
CHAPTER IX.

THROUGH THE AIR.

Flying-machine inventors and enthusiasts may be divided into two great classes, each of which is certain that it has discovered the only straight and narrow path to aërial navigation. Those who belong to the first of these classes place their faith in the steerable or dirigible balloon; they secure their lifting power with gas, and seek to control the direction of flight by various contrivances of wings and screw propellers. They are air soarers. Those of the second class go to the bird for their model. The bird, they assert, is nature's first and best flying machine; and if a bird, which is nearly a thousand times as heavy as the air it displaces, can soar for hours aloft without tiring, why shouldn't a man do the same, provided he can build the proper mechanism? Consequently these inventors, who have given the subject of bird flight long and serious attention, discard the balloon system with some-

thing of disdain, and plan their machines after the perfect model of a bird's wing.

Both of these methods have been thoroughly tested, and, what is more, with astonishing success, considering the difficulties which have had to be overcome. Balloon flying machines have really been steered, not to the limits of success, but far enough to demonstrate that the feat can be accomplished. On the other hand, a



WING OF A SOARING BIRD.

soaring or aëroplane machine has been constructed and actually made to fly for considerable distances; and yet more curious and interesting, a number of daring inventors have constructed real wings with which they have soared with success from hill-tops and high walls.

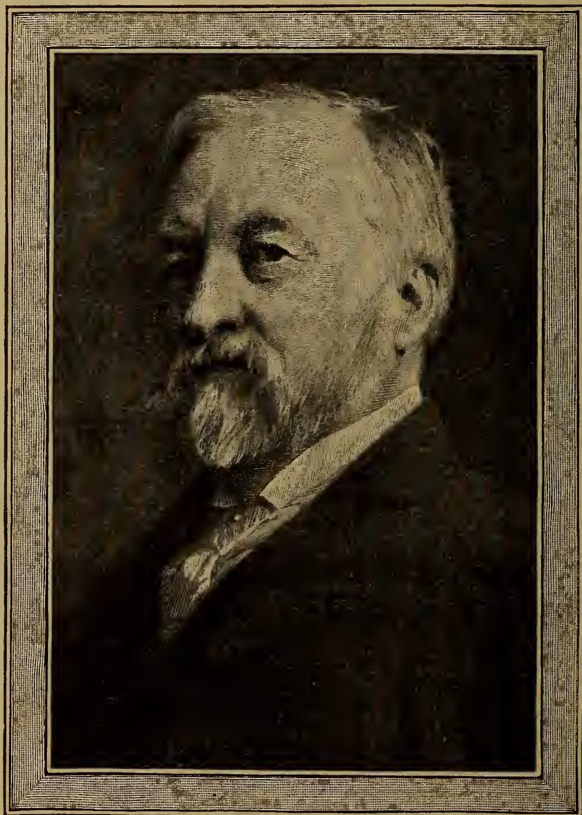
Both of these methods are, therefore, worthy of careful consideration, although in this chap-

ter I shall take up only flying machines proper —the aëroplanes and bird-like contrivances— the balloon machines or air floaters coming more properly under the important subject of ballooning.

I suppose more inventors have been fascinated with the idea of building a machine that would fly than with almost any other single subject, perpetual motion possibly excepted. Nearly every town has its flying-machine enthusiast, and the Patent Office at Washington is busy constantly with curious designs for winged mechanisms; and yet the perfect machine, the machine which will one day supplant the steamship, bankrupt the railroad, and annihilate space is yet to be invented. And invented it positively will be, perhaps by some reader of this book; for mathematicians have demonstrated its possibility by unerring figures, and it only remains for the clever mechanician to build the necessary machinery.

I shall not try to cover the whole story of the flying machine, which is almost as old as the inventive imagination of man, for it would fill a big book. I shall, rather, describe the efforts of a few of the inventors who have made the most notable recent achievements.

Probably no American inventor of flying machines is so well known and has been so



PROFESSOR S. P. LANGLEY.

From the painting by Robert Gordon Hardie, 1893.

successful in his experiments as Professor S. P. Langley, the distinguished secretary of the Smithsonian Institution at Washington. Professor Langley has built a machine with wings,

driven by a steam-engine, and wholly without gas or other lifting power beyond its own internal energy. And this machine, to which has been given the name Aërodrome (air-runner), actually flies for considerable distances. So successful were Professor Langley's early tests, that the United States Government recently made a considerable appropriation to enable him to carry forward his experiments in the hope of finally securing a practical flying machine. His work is, therefore, the most significant and important of any now before the public.

The invention of the aërodrome was the result of long years of persevering and exacting labor, with so many disappointments and setbacks that one cannot help admiring the astonishing patience which kept hope alive to the end. Early in his experiments, Professor Langley had proved positively, by mathematical calculations, that a machine could be made to fly, provided its structure were light enough and the actuating power great enough. Therefore he was not in pursuit of a mere will-o'-the-wisp. It was a mechanical difficulty which he had to surmount, and he surmounted it.

Professor Langley made his first experiments more than twelve years ago at Allegheny, Pennsylvania. He began, not by building a

flying machine, but with a thorough investigation into the theory of the flight of birds, in order to find out how much power was needed to sustain a surface of given weight by means of its motion through the air. For this purpose he built a very large "whirling table"—a device having an arm which swept around a central pivot, the outer end of which could be given a velocity of seventy miles an hour. Various objects were hung at the end of the arm and dragged through the air, until its resistance supported them just as a kite is supported by the wind. A plate of brass weighing one pound, for instance, was hung from the end of the arm by a spring, which was drawn out until it registered a pound weight when the arm was still. When the arm was in motion, it might be expected that, as it was drawn faster, the pull would be greater; but Professor Langley's observations, strangely enough, showed just the contrary, for under these circumstances the spring contracted until it registered less than an ounce. With the speed increased to that of a bird in flight, the brass plate seemed to float on the air. Preliminary experiments of this nature were continued for three long years, and Professor Langley formed the general conclusion that by simply moving any given weight in plate form fast enough in

a horizontal path through the air it was possible to sustain it with very little power. It was proved that, if horizontal flight without friction could be insured, 200 pounds of plates could be moved through the air and sustained upon it at the speed of an express train, with the expen-

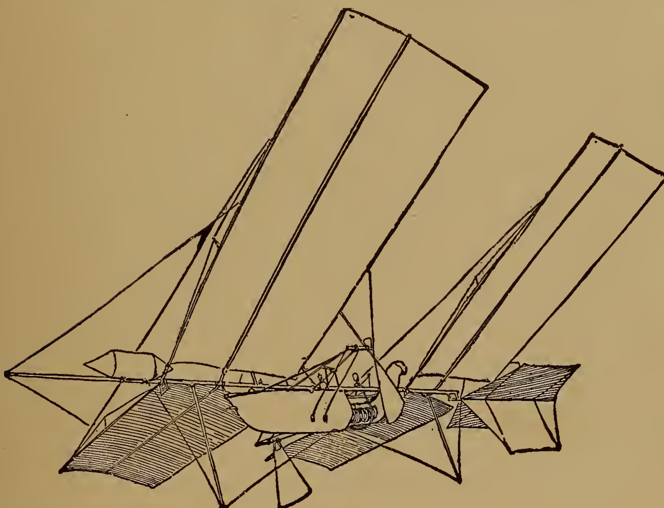


DIAGRAM OF THE FINAL AËRODROME.

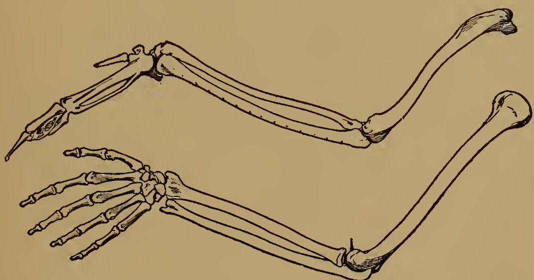
diture of only one horse-power, and that, of course, without using any gas to lighten the weight.

Every boy who has skated knows that when the ice is very thin he must skate rapidly, else he may break through. In the same way, a stone may be skipped over the water for consid-

erable distances. If it stops in any one place it sinks instantly. In exactly the same way, the plate of brass, if left in any one place in the air, would instantly drop to the earth; but if driven swiftly forward in a horizontal direction it rests only an instant in any particular place, and the air under it at any single moment does not have time to give way, so to speak, before it has passed over a new area of air. In fact, Professor Langley came to the conclusion that flight was theoretically possible with engines he could then build, since he was satisfied that engines could be constructed to weigh less than twenty pounds to the horse-power, and that one horse-power would support two hundred pounds if the flight was horizontal.

That was the beginning of the aërodrome. Professor Langley had worked out its theory, and now came the much more difficult task of building a machine in which theory should take form in fact. In the first place, there was the vast problem of getting an engine light enough to do the work. A few years ago an engine that developed one horse-power weighed nearly as much as an actual horse. Professor Langley wished to make one weighing only twenty pounds, a feat never before accomplished. And then, having made his engine,

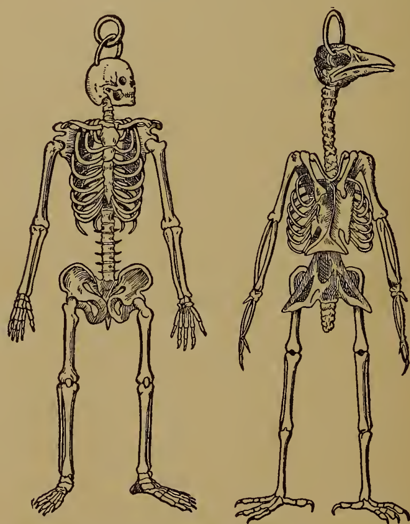
how was he to apply the power to obtain horizontal speed? Should it be by flapping wings like a bird, or by a screw propeller like a ship? This question led him into a close study of the bird compared with the man. He found how wonderfully the two were alike in bony formation, how curiously the skeleton of a bird's wing was like a man's arm, and yet he finally de-



BONES OF A BIRD'S WING AND OF A HUMAN ARM—SHOWING THEIR CLOSE RESEMBLANCE.

cided that flapping wings would not make the best propeller for his machine. Men have not adopted machinery legs for swift locomotion, although legs are nature's models, but they have, rather, constructed wheels—contrivances which practically do not exist in nature. Therefore, while Professor Langley admits that successful flying machines may one day be made with flapping wings, he began his experiments with the screw propeller.

There were three great problems in building the flying machine. First, an engine and boilers light enough and at the same time of sufficient power. Second, a structure which should be rigid and very light. Third, the



SKELETONS OF A MAN AND A BIRD DRAWN TO THE SAME SCALE, SHOWING THE CURIOUS RESEMBLANCE BETWEEN THEM.

enormously difficult problem of properly balancing the machine, which, Professor Langley says, "took years to acquire."

For his propelling power he tried compressed air, gas, electricity, carbonic-acid gas, and many other sources of energy, but he finally

settled on the steam-engine, and he succeeded, after all manner of difficulties, in building a mechanism light enough. He says in regard to this part of the work:

"The chief obstacle proved to be not with the engines, which were made surprisingly light after sufficient experiment. The great difficulty was to make a boiler, of almost no weight, which would give steam enough, and this was a most wearying one. There must be also a certain amount of wing surface, and large wings weighed prohibitively; there must be a frame to hold all together, and the frame, if made strong enough, must yet weigh so little that it seemed impossible to make it. These were the difficulties that I still found myself in after two years of experiment, and it seemed at this stage again as if it must, after all, be given up as a hopeless task, for somehow the thing had to be built stronger and lighter yet. Now, in all ordinary construction, as in building a steamboat or a house, engineers have what they call a factor of safety. An iron column, for instance, will be made strong enough to hold five or ten times the weight that is ever going to be put upon it; but if we try anything of the kind here the construction will be too heavy to fly. Everything in the work has got to be so light as to be on the edge of breaking

down and disaster, and when the breakdown comes, all we can do is to find what is the weakest part and make that part stronger; and in this way work went on, week by week and month by month, constantly altering the form of construction so as to strengthen the weakest parts, until, to abridge a story which extended over years, it was finally brought nearly to the shape it is now, where the completed mechanism, furnishing over a horse-power, weighs collectively something less than seven pounds. This does not include water, the amount of which depends on how long we are to run; but the whole thing, as now constructed, boiler, fire-grate, and all that is required to turn out an actual horse-power and more, weighs something less than one one-hundredth part of what the horse himself does."

From this it will be seen what tremendous difficulties had to be met and solved, and yet the machine could not fly independently, although the mechanical power was there.

Professor Langley established an experimental station in the Potomac River, some miles below Washington. An old scow was obtained, and a platform about twenty feet high was built on top of it. To this spot, in 1893, the machine was taken, and here failure followed failure; the machine would not fly properly,

and yet every failure, costly as it might be in time and money, brought some additional experience. Professor Langley found out that

PREPARING TO LAUNCH THE AERODROME.

From a photograph by A. Graham Bell, Esq.

the aërodrome must begin to fly against the wind, just in the opposite way from a ship. He found that he must get up full speed in his engine before the machine was allowed to

go, in the same way that a soaring bird must make an initial run on the ground before it can mount into the air, and this was, for various reasons, a difficult problem. And then there was the balancing.

"If the reader will look at the hawk or any

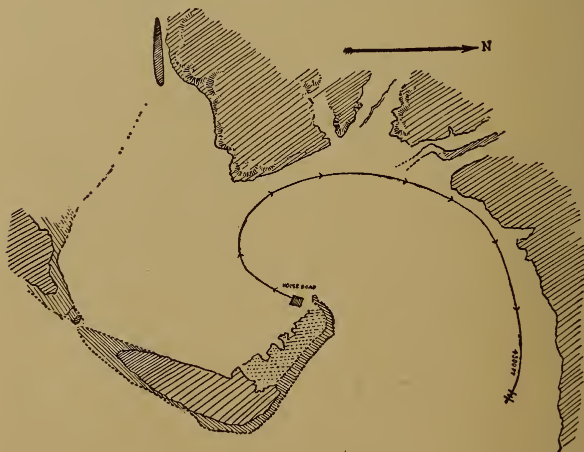


DIAGRAM SHOWING THE COURSE OF THE AERODROME IN ITS FLIGHT ON THE POTOMAC RIVER AT QUANTICO.

soaring bird," says Professor Langley, "he will see that as it sails through the air without flapping the wing, there are hardly two consecutive seconds of its flight in which it is not swaying a little from side to side, lifting one wing or the other, or turning in a way that suggests an acrobat on a tight-rope, only that

the bird uses its widely outstretched wings in place of the pole."

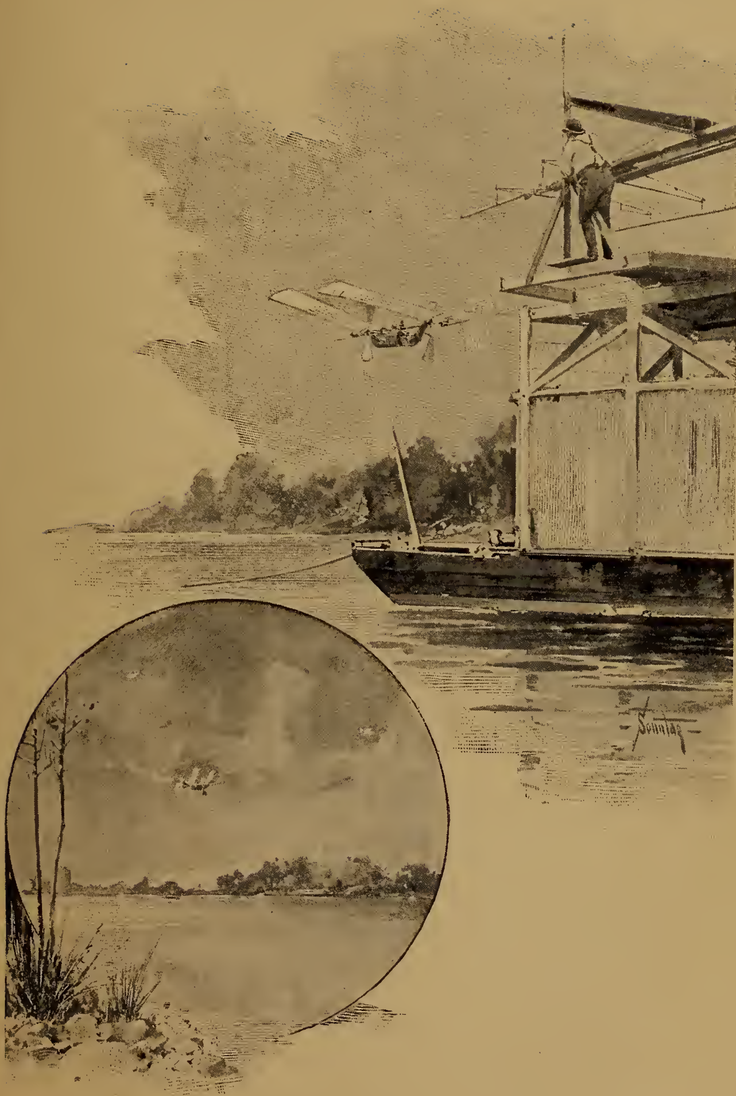
It must be remembered that air currents, unlike the Gulf Stream, do not flow steadily in one direction. They are forever changing and shifting, now fast, now slow, with something of the commotion and restlessness of the rapids below Niagara.

All of these things Professor Langley had to meet as a part of the difficult balancing problem, and it is hardly surprising that nearly three years passed before the machine was actually made to fly—on May 6, 1896.

"I had journeyed, perhaps for the twentieth time," says Professor Langley, "to the distant river station, and recommenced the weary routine of another launch, with very moderate expectation indeed; and when, on that, to me, memorable afternoon the signal was given and the aërodrome sprang into the air, I watched it from the shore with hardly a hope that the long series of accidents had come to a close. And yet it had, and for the first time the aërodrome swept continuously through the air like a living thing, and as second after second passed on the face of the stop-watch, until a minute had gone by, and it still flew on, and as I heard the cheering of the few spectators, I felt that something had been accomplished at

last; for never in any part of the world, or in any period, had any machine of man's construction sustained itself in the air before for even half of this brief time. Still the aërodrome went on in a rising course until, at the end of a minute and a half (for which time only it was provided with fuel and water), it had accomplished a little over half a mile, and now it settled, rather than fell, into the river, with a gentle descent. It was immediately taken out and flown again with equal success, nor was there anything to indicate that it might not have flown indefinitely, except for the limit put upon it."

Only a brief description of Professor Langley's machine, a very good idea of which may be had from the pictures, can here be given. It has two pairs of wings, each slightly curved, attached to a long steel rod from which hang the boilers, engines, and other machinery, and the propeller wheels. The hub itself is formed of steel tubing; in front there is a little conical float to keep the machine from sinking, should it fall in the water. The boiler weighs a little over five pounds, while the engine, which gives one and one-half horse-power, weighs only twenty-six ounces. The rudder is arranged for steering in four directions—up, down, to the right, and to the left, and all automatically.



THE AERODROME IN FLIGHT, MAY 6, 1896.

Two views from instantaneous photographs taken by A. Graham Bell, Esq.

The width of the wings from tip to tip is between twelve and thirteen feet, and the length of the whole about sixteen feet. The weight is nearly thirty pounds, of which about one-fourth is the machinery.

So much for Professor Langley's aërodrome, the first and most wonderful of machines of its kind. Hiram Maxim, the famous inventor of the Maxim gun, has experimented on a colossal affair of aëroplanes to carry three men—and she ran swiftly when her wheels rested firmly on the wide rails of her little railroad, but her inventor never has ventured to lift her free in the air. These two inventions, Langley's and Maxim's, have been the greatest efforts toward the utilization of the soaring plane.

The possibility of using wings for flight is one of the very oldest of mechanical ideas. It is so easy to say, "A bird flies; why shouldn't a man?" and more than one brilliant inventor has been dashed to death trying to answer this very question. What boy hasn't read of the amusing adventures of Darius Green? And yet of late years, wonderful enough, men *have* actually flown with wings, wings resembling those of a soaring bird. Only last year Lilienthal, the famous "flying man" of Berlin, was killed from a fall received while he was careering high above the earth with his great wings.

Chanute, an American inventor, has flown successfully with wings; and only recently Hargrave, the Australian inventor of the famous box-kite, has been making kite-like wings which

OTTO LILIENTHAL, "THE FLYING MAN."

he asserts will solve the great problem of practical aërial navigation.

Lilienthal, the flying man, built his wings after a long and close study of the flight of birds. He finally came to the conclusion that a bird is able to sustain itself without apparent effort in the air, and even to soar against the

wind, owing to the peculiar curved surface of its wings. The fins of many fishes and the web feet of aquatic birds are strikingly analogous in construction The sails of a ship as-

A START FROM A WALL.

sume a similar form. It would be impossible to sail so near the wind in beating if the instrument of propulsion were a rigid flat surface. It is the effort of the sail to get away from the wind which it gathers in its ample

bosom which drives the boat forward, almost in the very teeth of the breeze. The flying machine devised and used by Herr Lilienthal was designed rather for *sailing* than for *flying*, in the proper sense of the term; or, as he once

LILIENTHAL STARTING FROM A HILL.

said, "for being carried steadily and without danger, under the least possible angle of descent, against a moderate wind, from an elevated point to the plain below." It was made almost entirely of closely woven muslin, washed

with collodion to render it impervious to air, and stretched upon a ribbed frame of split willow, which was found to be the lightest and strongest material for this purpose. Its main elements were the arched wings; a vertical rud-

PREPARING FOR A START FROM A HILL.

der, shaped like a palm-leaf fan, which acted as a vane in keeping the head always towards the wind; and a flat, horizontal rudder, to prevent sudden changes in the equilibrium.

The operator so adjusted the apparatus to his person that, when in the air, he either rested

SOARING IN A STRONG BREEZE.

on his elbows or was seated upon a narrow support near the front. With the wings folded behind him, he made a short run from some elevated point, always against the wind, and when he attained sufficient velocity, launched

DESCENDING IN STILL AIR.

A DESCENT IN STILL AIR.

himself into the air by a spring or jump, at the same time spreading the wings, which were at once extended to their full breadth, whereupon he sailed majestically along like a gigantic sea-

THE DESCENT.

gull. In this way Herr Lilienthal often accomplished flights of three hundred yards and more from the starting-point.

"No one," Herr Lilienthal once explained, "can realize how *substantial* the air is until

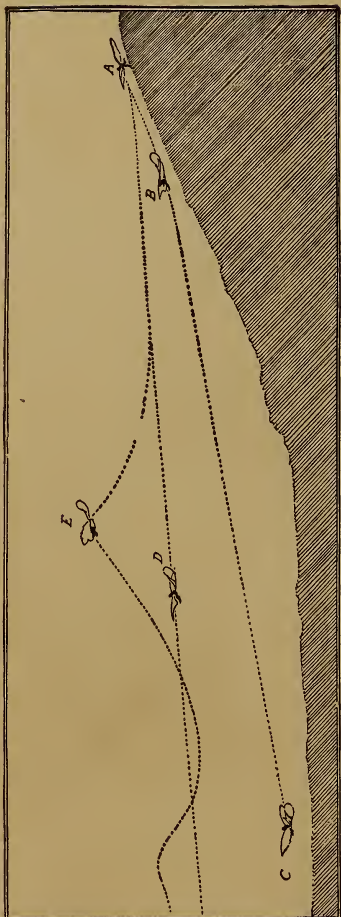


CHART OF ONE OF LILIENTHAL'S FLIGHTS.

A, The start. B, The gliding descent. C, Alighting in still air. D, Course in ten-mile breeze. E, Soaring in strong breeze.

he feels its supporting power beneath him. It inspires confidence at once. With flat wings it would be almost impossible to guard against a fall. With arched wings it is possible to sail against a moderate breeze at an angle of not more than six degrees to the horizon."

The principle is recognized in the umbrella form universally adopted for the parachute. Try to run with an open umbrella held above the head and slightly inclined back-

wards, and see what a lifting power it exerts.

Lilienthal spent many years of toil on his invention, and after his final perfected wings were finished, it required much skill and strength to use them successfully, to guide the direction of flight by careful movements of the arms, to go up by leaning back, and down by leaning forward. And at the last the inventor himself was hurled to his death, but not until he had contributed much to the knowledge of aëronautics.

Mr. Hargrave has contributed to scientific information a very clear statement as to why a bird is able to soar against the wind, and he is using his discoveries as the basis for a new invention in flying machines. Hargrave's idea is that the thick forward part of a bird's wing acts as an obstruction, like a dam in a river, causing a whirlpool below the wing, which rolls with great force against the back side of this obstruction, thereby forcing it forward. In other words, progress through the air is caused by an undertow of air. He suggests, therefore, a flying machine shaped somewhat in the form of a toboggan turned upside down. The wind, striking the edge of the toboggan curve in front, creates a whirlpool in the inverted hollow, and propels the whole machine forward

and upward, according to the way it is steered by the suspended ballast, which determines its angle of flight.

Each year the inventor presses closer to the great secret of human flight, each year the mechanic is able to build more perfect machinery, and the two, working side by side, may be expected before many years have passed to produce a flying machine which will be practically a success as well as an experimental success.

A SAFE LANDING.